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AIR CLEANERS FOR MOTOR VEHICLES

A. H. HOFFMAN

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A. H. HOFFMAN[1]

INTRODUCTION

The carbureter air cleaner is of vital importance to those who must have long, dependable, and economical service from their motor vehicles. Dust entering through the carbureter or the breather and mixing with the lubricating oil keeps grinding away whenever the engine is running and is the principal cause of rapid wear and the consequent early and frequent need of reboring cylinders and replacing pistons, rings and valves. A worn engine is uneconomical to use because it is less powerful and dependable and requires more fuel and oil to do the same work.

Numerous road tests made by various operators of stage lines and fleets of motor vehicles have shown that, if dust is kept out, the wear of engine parts will be reduced to about three-fourths in some machines and in others sometimes even to as little as one-eighth of what it would be for equivalent use without protection against dust.

The dust problem is not so serious to those who use their automobiles and trucks on paved roads only or who expect to 'turn in' their machines as soon as the high gloss is worn from the enamel or the upholstering becomes a bit shabby; but it is often very serious to those who must use dry earth roads and get long, economical service from their machines. The farmer, probably more than anyone else, uses motor vehicles in fields and orchards and on unpaved roads where dust conditions are often extremely severe; hence for him the air cleaner is of especial importance.

Inspection of the air-cleaning equipment on the automobiles exhibited at the San Francisco auto show last winter failed to reveal any cleaner of a kind able to protect adequately when the car is used under severe dust conditions, though most of the cars shown had some sort of a cleaner as regular equipment. Several of the prominent automobile manufacturers are, nevertheless, now keenly interested in the users' dust problem and are making elaborate tests to find air cleaners that will protect adequately. Recently manufacturers have installed crankcase oil filters on a large number of automobiles and trucks, and on three or four kinds of tractors. These, if serviced or renewed with sufficient regularity, serve to remove solid impurities

[1] Agricultural Engineer in the Experiment Station.

from the circulating oil. They cannot, however, take the place of the air cleaner, because the dust entering the engine by way of the carbureter and mixing with the oil on the cylinder walls must necessarily work down past pistons and rings and into the crankcase before the oil filter can remove it. Nevertheless a few road tests, made in cooperation with the California Highway Commission, have shown that such filters may decrease the wear by about 50 per cent under ordinary conditions even for the top piston rings.

Since the work done in 1922 on air cleaners for tractors,[2] samples of practically all the new air cleaners appearing on the market have been obtained and tested at the Branch of the College of Agriculture at Davis, California, to determine their efficiency in separating dust and their behavior as to choking or restricting the flow of air to the carbureter. Most of these cleaners are designed for automobiles or trucks, but a few are for tractors. The purpose of this bulletin is to report the results of such of these tests as are presumably of interest and value to the manufacturers and users of motor vehicles, together with the results of a general study of the dust problem, especially as it relates to wear in the engines of automobiles and trucks.

DESCRIPTION OF THE MORE IMPORTANT AIR CLEANERS STUDIED

The cleaners shown in figures 1 to 29 inclusive and identified by the data given in table 1 are the more important ones of those that have been under study and test at the Experiment station at Davis, California, since 1922. The figures and data are given primarily to make possible positive identification of the cleaners for which test results are given in table 3. The same figures and descriptions will serve the added purpose of giving a fair idea of what the present air cleaner market offers.

The cleaners of tables 1 and 3 may be grouped as to their characteristic differences of type as follows:

Dry filters, figures 1 to 6, pages 13 to 16.

Dry centrifugals, figure 7, page 16.

Low restriction oily filters, figures 8 to 15, and 22 and 23, pages 17 to 21 and 25 and 26.

Self-washing oily filter and metal surface types, figures 11 to 14 and 16 to 23, pages 19 and 26.

Miscellaneous, figures 24 to 29, pages 27 to 30.

[2] Hoffman, A. H. Dust and the tractor engine. California Agr. Exp. Sta. Bul. 362:467–486. 8 figs. 1923.

TABLE 1

IDENTIFICATION OF AIR CLEANERS

No.	Name and model	Weight clean, dry, lbs.	Outlet inside diameter, inches	Height, length, width, or diameter (d.), of body proper, inches	Elbow in outlet?	Material		Made by
						Body	Filter, if any	
36	Bennett, dry centrifugal and oily fiber filter	3.40	1 29/32	3½x 6½ d.	Yes	Sheet steel	Fiber, close packed	Bennett Carbureter Co., 101 First Ave., North, Minneapolis, Minn.
37	Bennett, dry centrifugal and oily fiber filter	2.90	1 11/16	3 x 6 d.	Yes	Sheet steel	Fiber, close packed	Bennett Carbureter Co., 101 First Ave., North, Minneapolis, Minn.
38	Bennett, dry centrifugal and oily fiber filter	1.90	1 13/16	2⅝x4½ d.	Yes	Sheet steel	Fiber, close packed	Bennett Carbuereter Co., 101 First Ave., North, Minneapolis, Minn.
39	Donaldson Simplex, oily fiber filter	3.30	2	8⅜x6 d.	No	Sheet steel	Fiber, close packed	Donaldson Company, Inc., 666 Pelham St., St. Paul, Minn.
40	Donaldson Simplex, oily fiber filter	2.10	1 23/32	8x4 d.	No	Sheet steel	Fiber, close packed	Donaldson Company, Inc., 666 Pelham St., St. Paul, Minn.
42	Gordon, rubber sponge filter	5.70	1 15/16	4⅜x10 d.	No	Sheet steel	Sponge rubber	Gordon Air Filter Co., 1013 Continental Bldg., Kansas City, Mo.
59	Midwest, Model T-1 self-washing metal plate	7.40	2	8x5x8½	No	Cast aluminum	Expanded steel	Midwest Air Filters, Inc., Bradford, Pa.†
65-A	AC (1926), dry centrifugal collector	1.00	1 13/16	4½x4 d.	No	Sheet steel		AC Spark Plug Co., Flint, Michigan.
66	Eddy (Spencer), inertia and dry filter	1.20	2-in. pipe	7x6 d.	No	Pressed steel	Organic fibers	Spencer Pneumatic Specialties Corp., Chicago, Ill.†
74	Zenith, Type II, dry centrifugal and felt filter	2.80	2 ¾	8x6 d.	No	Pressed and cast aluminum	Felt	Ste. du Carburateur Zenith, Paris, France.

† Merged with American Air Filter Co., Inc., First and Central Aves., Louisville, Ky.

TABLE 1—(Continued)

No.	Name and model	Weight clean, dry, lbs.	Outlet inside diameter, inches	Height, length, width, or diameter (d.), of body proper, inches	Elbow in outlet?	Material		Made by
						Body	Filter, if any	
75	Tillotson, OW 500, centrifugal collector and filter	1.25	1 7/8	5½x4½ d.	No	Aluminum	Cotton cloth	Tillotson Mfg. Co., Toledo, Ohio.
76	Tillotson, OW 560, centrifugal collector	1.00	1 7/8	4x4½ d.	No	Pressed steel		Tillotson Mfg. Co., Toledo, Ohio
77	Air-Maze, 3 ST, oily screen filter	1.30	2 3/8	4⅝x4⅝ d.	No	Pressed steel	Wire screen	Air-Maze Corp., 321 Caxton Bldg., Cleveland, O.
78	Remington helicoid, oily (removable)	0.70	1 5/8	4½x2½ d.	No	Brass and aluminum		Rectifier Mfg. Co., 1755 Broadway, New York
79	Remington, helicoid, oily, (fixed)	0.80	2	5½x2⅝ d.	No	Pressed steel		Rectifier Mfg. Co., 1755 Broadway, New York.
84	Winslow Purifier, oily fiber filter	3.40	2	6½x5¼ d.	No	Cast aluminum	Organic fibers	Michiana Products Corp., Michigan City, Ind.
*85	Visco Rotary, revolving oily plates	10.85	1 15/16	10½x8½x6	Yes	Cast aluminum	Steel plates	Visco Engineering Co., Ltd., 162, Grosvenor Road, London, S. W. 1.
87	Protectomotor, C-4, dry felt filter	2.40	1 7/8	7½x6¼ d.	No	Pressed aluminum	Felt	Staynew Filter Corp., Rochester, N. Y.
88	AC, dry centrifugal ejector	0.60	1 3/4	4⅝x4 d.	No	Pressed steel		AC Spark Plug Co., Flint, Mich.
89	AC, dry centrifugal ejector	0.58	2 1/32	3⅝x4⅛ d.	No	Pressed steel		AC Spark Plug Co., Flint, Mich.
90	AC, oily copper strip filter	0.75	1 13/16	4½x4⅛ d.	No	Pressed steel		AC Spark Plug Co., Flint, Mich.
91	Vortox, Model 270, self-washing filter	3.50	1 ½	9x4 d.	Yes	Cast aluminum, top, pressed steel	Kinked steel wire	Vortox Mfg. Co., Claremont, Calif.
*92	Vortox, Model 850, self-washing filter	4.80	2	11x4½ d.	Yes	Cast aluminum, top pressed steel	Kinked steel wire	Vortox Mfg. Co., Claremont, Calif.

*Designed for large trucks or for tractors.

TABLE 1—(Continued)

No.	Name and model	Weight clean, dry, lbs.	Outlet inside diameter, inches	Height, length, width, or diameter (d.), of body proper, inches	Elbow in outlet?	Material		Made by
						Body	Filter, if any	
*93	Vortox, Model 750, self-washing filter	6.80	2	12x5½ d.	Yes	Cast aluminum, top pressed steel	Kinked steel wire	Vortox Mfg. Co., Claremont, Calif.
94	United (Chrysler), dry centrifugal	0.87	1 ½	3x4 d.	Yes	Pressed steel		United Air Cleaner Co., 9705 Cottage Grove Ave., Chicago, Illinois
95	United (Chrysler), dry centrifugal	1.37	1 ¾	3x4½ d.	Yes	Pressed steel		United Air Cleaner Co., 9705 Cottage Grove Ave., Chicago, Illinois
*96	Vortox, Model 1000, self-washing filter	7.70	2	14½x6½ d.	Yes	Cast aluminum, top pressed steel	Kinked steel wire	Vortox Mfg. Co., Claremont, Calif.
97	Donaldson, (for Ford), oily fiber filter	0.30	1 ⅞	2½x3¼ d.	No	Pressed steel	Organic fibers	Donaldson Co., Inc., 666 Pelham St., St. Paul, Minn.
98	Bowden, for Ford A, thin oily pasteboard	1.41	1 ⅝	3⅞x4⅛ d.	Yes	Pressed steel	Pasteboard	J. A. Bowden, 657 So. Cochran St., Los Angeles, Calif.
100	Bowden, thin oily pasteboard	2.44	1 13/16	3½x5¼ d.	Yes	Aluminum elbow, pressed steel	Pasteboard	J. A. Bowden, 657 So. Cochran St., Los Angeles, Calif.
101	Bowden, thin oily pasteboard	2.80	1 13/16	4½x5¼ d.	No	Pressed steel	Pasteboard	J. A. Bowden, 657 So. Cochran St., Los Angeles, Calif.
*108	Winslow Down-Flo, self-washing screen filter	10.65	2 ¼	12x6 d.	No	Aluminum and sheet steel	Wire screen	Michiana Products Corp., Michigan City, Indiana
*108 B	Winslow Down-Flo, self-washing hair filter	7.97	2 ¼	12x6 d.	No	Aluminum and sheet steel	Curled hair	Michiana Products Corp., Michigan City, Indiana

*Designed for large trucks or for tractors.

TABLE 1—(Continued)

No.	Name and model	Weight clean, dry, lbs.	Outlet inside diameter, inches	Height, length, width, or diameter (d.), of body proper, inches	Elbow in outlet?	Material		Made by
						Body	Filter, if any	
*108 C	Winslow Down-Flo, self-washing screen filter	10.55	$2\frac{1}{4}$	12x6 d.	No	Aluminum and sheet steel	Wire screen	Michiana Products Corp., Michigan City, Indiana
109	United, rotor, dry centrifugal	1.40	$1\frac{5}{16}$	$4x4\frac{1}{2}$ d.	No	Sheet steel		United Air Cleaner Corp., 9705 Cottage Grove Ave., Chicago, Ill.
110	United, "$4\frac{1}{2}$ in." horizontal dry centrifugal, 4 slots	1.13	$2\frac{1}{16}$	$3\frac{1}{2}x4\frac{1}{2}$ d.	No	Sheet steel		United Air Cleaner Corp., 9705 Cottage Grove Ave., Chicago, Ill.
111	Handy, dry centrifugal, 1 slot	0.80	$1\frac{13}{16}$	$3\frac{1}{8}x4\frac{3}{8}$ d.	Yes	Sheet steel		Handy Cleaner Corp., 3925 W. Fort St., Detroit, Mich.
112	Handy, dry centrifugal, 1 slot	0.70	$2\frac{1}{16}$	$3\frac{1}{8}x4\frac{3}{8}$ d.	No	Sheet steel		Handy Cleaner Corp., 3925 W. Fort St., Detroit, Mich.
*113	Donaldson (tractor), dry centrifugal and oily filter	6.87	$2\frac{1}{2}$	15x6 d.	No	Sheet steel	Closely packed organic fiber	Donaldson Co., Inc., 666 Pelham St., St. Paul, Minn.
114	Annis Air Filter, dry felt filter	7.70	$1\frac{3}{4}$	$10\frac{1}{2}x7x7$	Yes	Aluminum and sheet steel	Felt	E. F. Annis, 1515 Gardena St., Glendale, Calif.
115	Vortox, Model 135, self-washing filter	5.20	2	$12x4\frac{1}{2}$ d.	Yes	Aluminum and sheet steel	Kinked steel wire	Vortox Mfg. Co., Claremont, Calif.
*116	Winslow, Model M, oily fiber filter	9.70	$2\frac{13}{16}$	16x7 d.	No	Sheet steel	Organic fibers	Michiana Products Corp., Michigan City, Ind.
*117	H-W Filtrator for Air, oily fiber filter	16.66	$2\frac{15}{16}$	19x8 d.	No	Aluminum and sheet steel	Organic fibers	Michiana Products Corp., Michigan City, Ind.
118	United, for Model A Ford, dry centrifugal, 4 slots	0.62	$1\frac{1}{2}$	$3x3\frac{1}{2}$ d.	Yes	Sheet steel		United Air Cleaner Co., 9705 Cottage Grove Ave., Chicago, Ill.

*Designed for large trucks or for tractors.

TABLE 1—(Continued)

No.	Name and model	Weight clean, dry, lbs.	Outlet inside diameter, inches	Height, length, width, or diameter (d.), of body proper, inches	Elbow in outlet?	Material		Made by
						Body	Filter, if any	
119	Protectomotor, Model C-4, dry felt filter	2.50	1 7/8	(Same as No. 87, except better quality felt.)				Staynew Filter Corp., Rochester, New York.
119A	Protectomotor, Model C-4, dry felt filter	(This cleaner is like No. 119, but had been used on a truck for four years before it was given the road test of vacuum reported in table 4 and figure 36.)						
122	Tillotson, Model X-1, dry centrifugal collector	1.13	1 7/8	4x4½ d.	No	Pressed steel		Tillotson Mfg. Co., Toledo, Ohio
123	Reed Model 6E1, oily wire filter	4.60	2-in. pipe	6x6½ d.	No	Sheet steel	Kinked steel wire	Reed Air Filter Co., Louisville, Ky.
*124 *A*	Imperial, self-washing filter	6.75	2	14⅛x6½	Yes	Sheet steel	Kinked steel wire	H. B. Anglemeyer, 135 E. Eldorado St., Pomona, Calif.
125	National, for Model A Ford, oily hair filter	0.65	1 ¾	4x3½ d.	Yes	Pressed steel, hardware cloth	Curled hair loosely packed	National Air Filter Co., Dayton, Ohio.†
128	Bowden, for Model A Ford, oily pasteboard	0.75	1 7/8	4x4 d.	Yes 45°	Hardware cloth, sheet steel	Pasteboard, 3/32 in.	J. A. Bowden, 657 So. Cochran St., Los Angeles, Calif.
129	Bowden, for Franklin, oily pasteboard	2.20	1 13/16	4x5 d.	Yes	Aluminum top, hardware cloth	Pasteboard, 3/32 in.	J. A. Bowden, 657 So. Cochran St., Los Angeles, Calif.
*130	Imperial, self-washing filter	4.50	1 15/16	10x4 d.	Yes	Sheet steel, top brass	Kinked steel wire	H. B. Anglemeyer, 135 E. Eldorado St., Pomona, Calif.
*132	Imperial, self-washing filter	9.00	2 ¼	12¼x5½ d.	Yes	Sheet steel, top brass	Kinked steel wire	H. B. Anglemeyer, 135 E. Eldorado St., Pomona, Calif.

* Designed for large trucks or for tractors. † Merged with American Air Filter Co., Inc., First and Central Aves., Louisville, Ky.

TABLE 1—(Continued)

No.	Name and model	Weight clean, dry, lbs.	Outlet inside diameter, inches	Height, length, width, or diameter (d.), of body proper, inches	Elbow in outlet?	Material: Body	Material: Filter, if any	Made by
133	Gordon, 5-inch dry felt filter	1.75	2	5x5 d.	No	Sheet steel, hardware cloth	Felt 1/4 inch thick	Gordon Air Filter Co., 1013 Continental Bldg., Kansas City, Mo.
134	Gordon, 6-inch dry felt filter	2.00	2	6 1/4x5 d.	No	Sheet steel, hardware cloth	Felt 1/4 inch thick	Gordon Air Filter Co., 1013 Continental Bldg., Kansas City, Mo.
135	Gordon, 8-inch dry felt filter	2.25	2	8x5 d.	No	Sheet steel, hardware cloth	Felt 1/4 inch thick	Gordon Air Filter Co. 1013 Continental Bldg., Kansas City, Mo.
136	National, for Buick '28, oily hair filter	0.75	1 13/16	3 7/8x3 1/2 d.	No	Pressed steel, hardware cloth	Curled hair	National Air Filter Co., Dayton, Ohio†
138	Air-Maze, for Model A Ford, oily screen filter	1.25	1 5/8	6 1/2x3 1/2 d.	Yes	Pressed steel, cast aluminum	Wire screen	Air-Maze Corp., 321 Caxton Bldg., Cleveland, O.
*140	Case, (tractor), self-washing oily screen filter	34.75	1 15/16	14x10x6	No	Cast iron	Wire screen	The Case Company, Racine, Wis.
*141	Miller, self-washing, oily filter	10.00	1 15/16	16x8 d.	No	Sheet steel	Steel wool	A. W. Miller, 431 State St., Milwaukee, Wis.
143	Bowden, for Model A Ford, oily pasteboard	1.40	1 3/4	5 1/2x4 d.	Yes	Sheet steel, hardware cloth, cast aluminum	Pasteboard, 3/64 in.	J. A. Bowden, 657 So. Cochran St. Los Angeles, Calif.
144	Winslow, self-washing oily screen	3.00	1 7/8	8 1/2x5 d.	Yes	Pressed steel, cast aluminum	Wire screen	Michiana Products Corp., Michigan City, Ind.
*145	AC Triplex Heavy Duty, copper ribbon filter	7.25	1 7/8x3 3/4	11x5 1/2 d.	No	Pressed steel, cast aluminum	Copper ribbon	AC Spark Plug Co., Flint, Michigan

* Designed for large trucks or for tractors. † Merged with American Air Filter Co., Inc., First and Central Aves., Louisville, Ky.

TABLE 1—(Continued)

No.	Name and model	Weight clean, dry, lbs.	Outlet inside diameter, inches	Height, length, width, or diameter (d.), of body proper, inches	Elbow in outlet?	Material: Body	Material: Filter, if any	Made by
146	Bowden, for Model A Ford, oily pasteboard filter	1.45	1⅝	5¼x4 d.	Yes	Pressed steel, hardware cloth, cast aluminum	Pasteboard, ³⁄₆₄ in.	J. A. Bowden, 657 So. Cochran St., Los Angeles, Calif.
147	Bowden, for 1930 Chrysler "70," oily pasteboard filter	1.88	2 ¾	4½x5 d.	No	Pressed steel, hardware cloth	Pasteboard, ³⁄₆₄ in.	J. A. Bowden, 657 So. Cochran St., Los Angeles, Calif.
148	Air-Maze, for 1930 Chrysler "70," oily screen filter	2.50	2 ¾	4½x5¾ d.	No	Pressed steel	Wire screen	Air-Maze Corp., 321 Caxton Bldg., Cleveland, O.
*149	Midwest, Model SD-5, self-washing oily surface	19.50	2-in. pipe	13x12x4½	No	Steel plate		Midwest Air Filters, Inc., Bradford, Pa.†
150	Bowden, for Model A Ford, oily pasteboard filter	1.50	1 ⅝	5¾x4 d.	Yes	Pressed steel, hardware cloth, cast aluminum	Pasteboard, ³⁄₆₄ in.	J. A. Bowden, 657 So. Cochran St., Los Angeles, Calif.
151	Morse, Type B, dry cloth filter	2.00	1¹¹⁄₁₆	9x4 d.	Yes (2)	Pressed steel, hardware cloth, cast aluminum	Cloth	Bullet Air Cleaner Co., 2418 3rd St., Santa Monica, Calif.
152	Morse, Type A, dry cloth filter	1.63	1¹³⁄₁₆	4½x4 d.	Yes (2)	Pressed steel, hardware cloth, cast aluminum	Cloth	Bullet Air Cleaner Co., 2418 3rd St., Santa Monica, Calif.
*153	Miller, self-washing oily filter	5.38	2	15x6 d.	Yes	Sheet steel	Steel wool	A. W. Miller, 431 State St., Milwaukee, Wis.
154	AC (from Graham-Paige), oily copper strip	0.50	4 ½	2½x4½ d.	No	Shee tsteel	Copper ribbon	AC Spark Plug Co., Flint, Mich.
*155	R. & H., self-washing oily filter	3.75	2	10⅛x5 d.	Yes	Sheet steel	Steel woo	R. & H. Company, Highland, Ill.
157	United, dry centrifugal and oily kinked wire filter	3.00	2 ⅝	6½ x 6 d.	No	Sheet steel	Wire screen and kinked steel wire	United Air Cleaner Corp., 9705 Cottage Grove Ave., Chicago, Ill.

* Designed for large trucks or for tractors. † Merged with American Air Filter Co., Inc., First and Central Aves., Louisville, Ky.

TABLE 1—(Concluded)

No.	Name and model	Weight clean, dry, lbs.	Outlet inside diameter, inches	Height, length, width, or diameter (d.), of body proper, inches	Elbow in outlet?	Material: Body	Material: Filter, if any	Made by
160	Annis, dry felt filter	13.50	2 1/2	9 1/4x13x6 1/2	No	Sheet steel and cast aluminum	Felt	E. F. Annis, 1515 Gardena St., Glendale, Calif.
161	Bowden, for Model A Ford, oily pasteboard	1.50	1 7/8	5 3/4x4 d.	Yes	Sheet steel, hardware cloth and cast aluminum	Pasteboard	J. A. Bowden, 657 S. Cochran St., Los Angeles, Calif.
162	Earnest, Model F, oily metal ribbon filter	0.80	1 7/8	3 1/2 x 4 d.	Yes	Sheet metal and cast aluminum	Braided metal ribbon	Geo. E. Adams, W. 3003 Dalton Ave., Spokane, Wash.
163	Earnest, Model C-3, oily metal ribbon filter	1.20	2 1/8	4 5/8x4 d.	Yes	Sheet metal and cast aluminum	Braided metal ribbon	Geo. E. Adams, W. 3003 Dalton Ave., Spokane, Wash.
164	C. R. C., Model No. 3, oily surface type	6.20	2 3/4	8 1/2x7 1/2x4	Yes	Aluminum	(Dust catching surfaces) felt and steel	Specialty Mfg. Corp., 914 First Ave., Spokane, Wash.
165	C. R. C., Model No. 2A, oily surface type	5.25	2 1/8	8x6 1/2x3 1/2	Yes	Aluminum	(Dust catching surfaces) felt and steel	Specialty Mfg. Corp., 914 First Ave., Spokane, Wash.
167	Hinkle, self-washing oily filter	3.50	2 1/16	11 3/4x5 3/4 d.	No	Sheet metal	Screen and metal shavings	R. V. Hinkle, Pendleton, Oregon.
168	Ellis, Model A, self-washing oily filter	3.75	2 1/8	10x5 3/4 d.	No	Sheet metal	Steel wool	Ellis Mfg. Co., Pendleton, Ore.
169	United Absolute, dry centrifugal and oily filter	3.60	2 3/4	6x6 d.	No	Pressed steel	Kinked wire held by screen	United Air Cleaner Corp., 9705 Cottage Grove Ave., Chicago, Ill.
170	Ellis, Model A, self-washing oily filter	4.00	2 1/16	10x5 3/4 d.	No	Sheet metal	Steel wool	Ellis Mfg. Co., Pendleton, Ore.
171	Ellis, Model C ("combine type"), self-washing oily filter	6.25	2 1/4	14x6 d.	No	Sheet metal	Steel wool	Ellis Mfg. Co., Pendleton, Ore.
173	C. R. C. 2-6 sp., oily surface type	5.70	2 1/4	8x6x4	No	Cast aluminum	(Dust catching surfaces) steel and felt	Specialty Mfg. Corp., Spokane, Wash.
174	C. R. C., 2-8 sp., oily surface type	5.70	2 1/4	8x6x4	No	Cast aluminum	(Dust catching surfaces) steel and felt	Specialty Mfg. Corp., Spokane, Wash.

For many of the cleaners listed the data in table 1 and the group photographs, figures 1, 7, 8, 16, and 24 will be sufficient identification and description. Many of the newer makes and newer models of old established makes have features that require fuller description. As will be noted, a few of the cleaners had to be included in more than one classification. Several cleaners are shown in separate figures because received too late for inclusion in the group photographs.

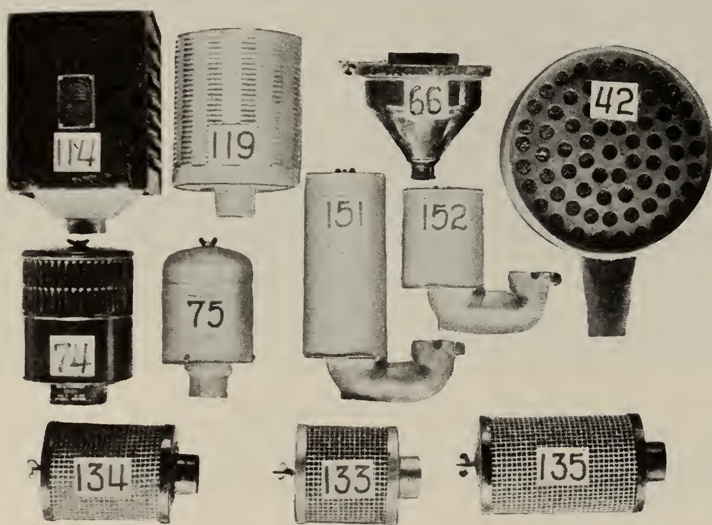


Fig. 1.—Dry filters. No. 114, Annis, felt; No. 66, Eddy (Spencer), hair; Nos. 133, 134, and 135, Gordon, felt; No. 42, Gordon, rubber sponge; Nos. 151 and 152, Morse, cloth; No. 119, Protectomotor, felt (see also fig. 3); No. 75, Tillotson, dry centrifugal and cloth (see also fig. 5); No. 74, Zenith (French), dry centrifugal and felt (see also fig. 4). *Not shown:* No. 160, Annis, felt (fig. 2); No. 87, Protectomotor, similar to 119.

Dry Filters.—Dry filters are shown in figure 1. No. 114 Annis, has a number of filter elements of practically pure wool felt about 0.036 in. thick drawn over flat frames of wire. No. 160, Annis, is a similar later model shown disassembled in figure 2. No. 119, Protectomotor, secures large area of practically pure wool, 0.036 in. thick felt in small space by the fluted construction shown in figure 3. The central tube is drilled at intervals with small holes so that compressed air may be used to blow out the dust without disassembling the cleaner. No. 87, Protectomotor (not shown), is similar in shape to No. 119 but has felt about 90 per cent cotton and about 0.025 in. thick. No. 74, Zenith, has two dry centrifugal cleaners in concentric shells and a thin felt filter in series. The filter consists of felt tubes drawn over spiral springs (fig. 4). No. 75, Tillotson Model OW 500,

combines a dry centrifugal which collects dust in a removable cup at the top with a fabric filter operative at low engine speeds, but designed to be by-passed by a valve that opens at higher engine speeds.

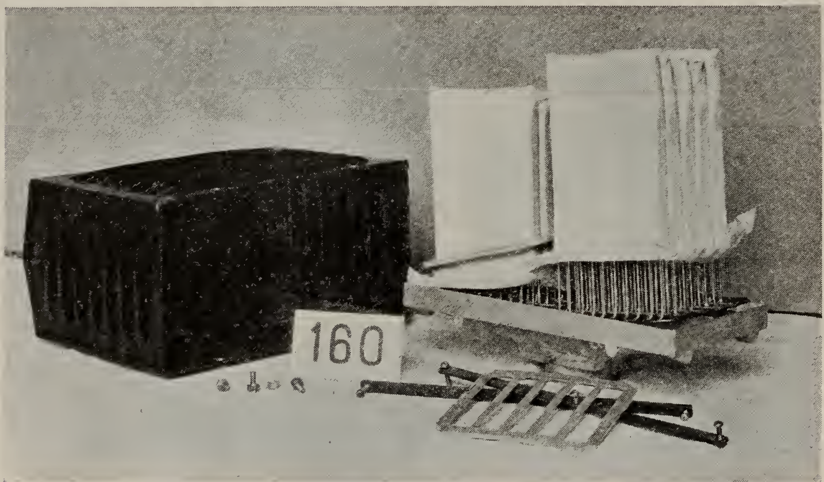


Fig. 2.—No. 160, Annis dry felt filter (disassembled). Each of the flat felt bags (10 in this model) forming the filter element is drawn over a wire frame. The two aluminum grids and iron bars hold down the filter element, prevent air leakage, and maintain the ½-inch spacing between the bags. New felts may be put in when needed.

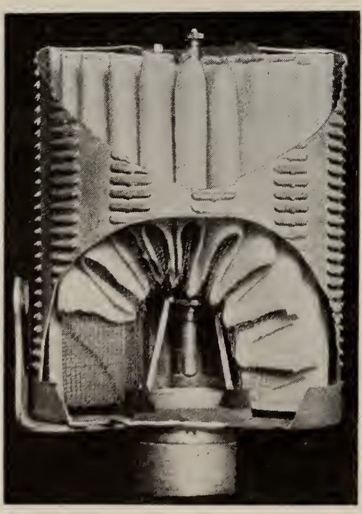


Fig. 3.—No. 119, Protectomotor. (Parts of shell and filter element are cut away.) By removing the cap at the top and applying an air hose to the perforated central tube much of the accumulated dust may be blown out. Note the method used to secure large filter area in small space.

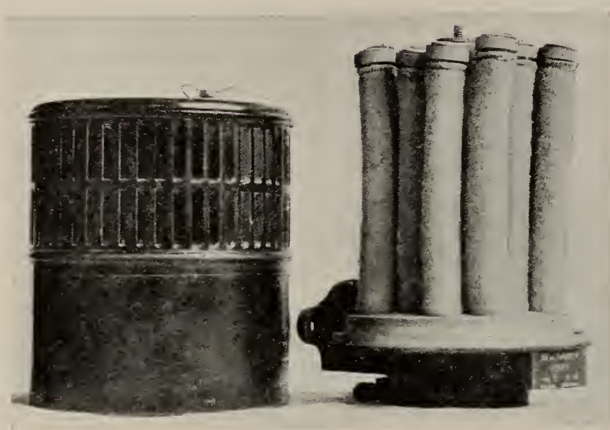


Fig. 4.—No. 74, Zenith. Two concentric shells form dry centrifugal cleaners in series with the tubular felt filter. Within each felt tube is a spiral spring.

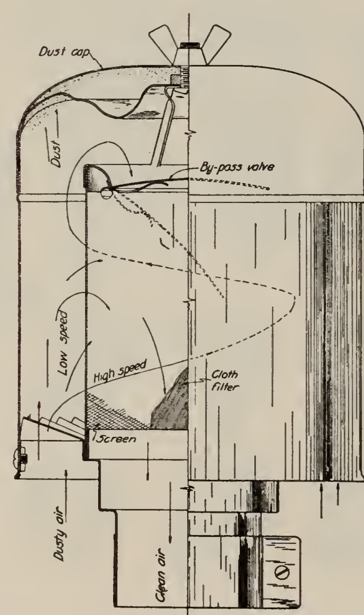


Fig. 5.—No. 75, Tillotson (shown partly broken away). The cloth filter in the middle is designed to operate at low speed. At high speed a by-pass valve opens, and cleaning thereafter is by centrifugal action.

Figure 5 shows the construction. Nos. 151 and 152, Morse, are plain cylindrical filters of thin tightly woven fabric. Nos. 133, 134, and 135, Gordon, are plain cylindrical filters of felt about ¼ in. thick. No. 42, Gordon, is a rubber-sponge type no longer manufactured. No. 66, Spencer, is a curled-hair filter designed especially for air compressors but also usable for automobiles. Figure 6 shows the construction; note the dust outlet valve at the bottom.

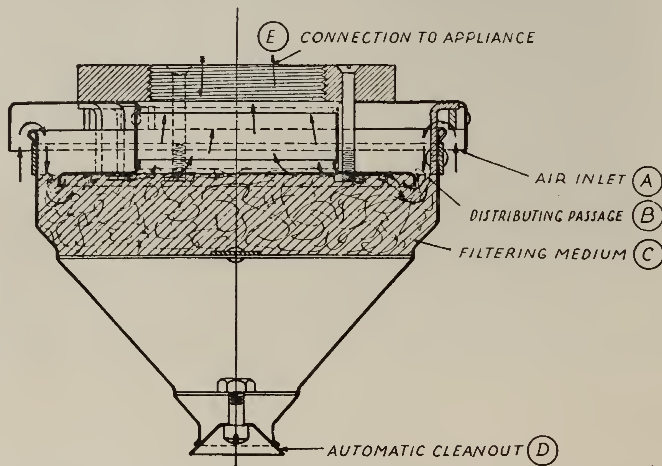


Fig. 6.—No. 66, Eddy (Spencer) (section view). A combination inertia and dry curled hair filter cleaner designed especially for air compressors but usable for gasoline engines.

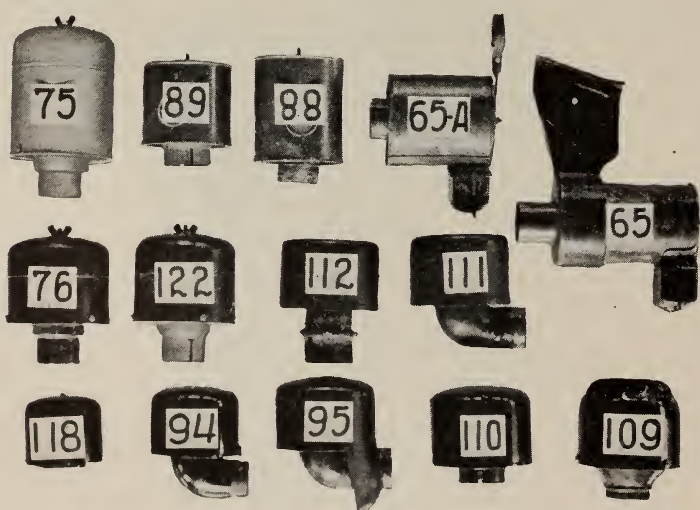


Fig. 7.—Dry centrifugals. No. 65, AC, old collector with stove; Nos. 88 and 89, AC, ejectors; Nos. 111 and 112, Handy, ejectors; No. 75, Tillotson, collector with filter for slow speed; Nos. 76 and 122, Tillotson, collectors; No. 109, United, with rotor; No. 110, United, ejector with 4 slots; No. 118, United for Model A Ford, ejector with 4 slots; Nos. 94 and 95, United, ejector without rotor or slots.

Dry Centrifugals.—Dry centrifugal filters are shown in figure 7. Nos. 65 and 65*A*, AC, are older collecting models included because many are still in use and because they are somewhat more efficient (when properly gasketed and serviced) than the newer ejecting models, such as Nos. 88 and 89. No. 76, Tillotson, OW 560, and No. 122, X–1, are collectors similar to No. 75 (described under "Dry Filters," p. 13), but do not have a filter element. Nos. 111 and 112, Handy, are one-slot ejectors. Nos. 110 and 118, United, are 4-slot ejectors; Nos. 94 and 95, United, are without rotor or slots, the separated dust being expected to fall out by gravity through the same openings by which the dusty air enters; No. 109, United, is an ejector with rotor.

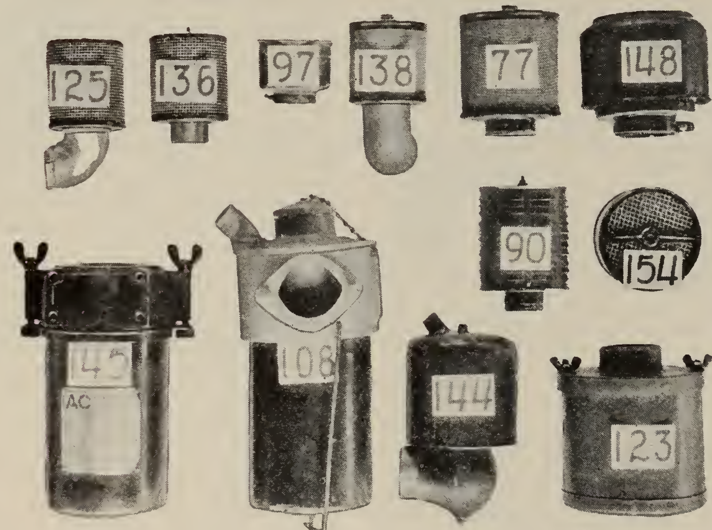
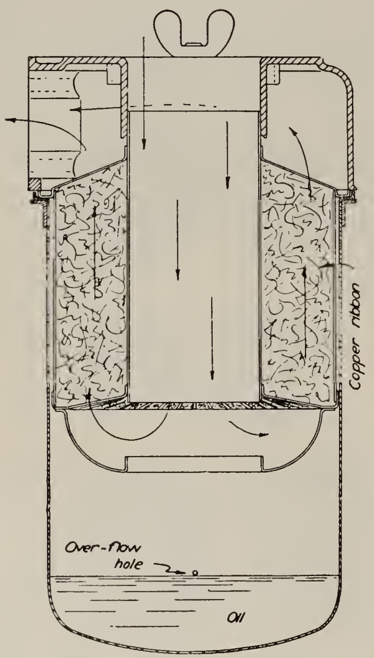


Fig. 8.—Low-restriction oily filters. No. 90, AC (copper ribbon) (see also fig. 10), and No. 154, same for Graham-Paige; No. 145, AC Triplex, copper ribbon (see also fig. 9); Nos. 77 and 138, Air-Maze 3 ST for Model A Ford, and No. 148, same for '30 Chrysler 70, wire screen; No. 97, Donaldson for Model A Ford, fiber; No. 125, National for Model A Ford, and No. 136, for '28 Buick, curled hair; No. 123, Reed, kinked steel wire; No. 108, Winslow Down-Flo, dry centrifugal and self-washing screen (see also fig. 11); No. 144, Winslow, dry centrifugal and self-washing screen (see also fig. 12). *Not shown:* No. 140, Case, tractor, self-washing screen (figs. 13 and 14); No. 162, Earnest, for Model A Ford, and No. 163, same for Buick, braided metal ribbon (fig. 15); Nos. 168, 170, and 171, Ellis, self-washing steel wool filters (fig. 23); No. 167, Hinkle, self-washing screen and metal shavings filter (fig. 22); No. 157, United, and No. 169, United 'Absolute,' dry centrifugal and kinked steel wire filter (fig. 27); Nos. 108*B* and 108*C*, Winslow Down-Flo, same as No. 108 except as to make-up of filter element.

Low-Restriction Oily Filters.—Figure 8 shows various low-restriction oily filters. No. 125, National, for Model A Ford, and No. 136, National for '28 Buick, are hollow cylinders of loosely packed curled

hair supported by concentric cylinders of hardware cloth spaced about ⅝ in. apart. No. 97, Donaldson Simplex for Model A Ford, is a plain, disk-shaped filter of loosely packed fiber. Nos. 77 Air-Maze, and 138, Air-Maze for Model A Ford, have three double, flat layers and two double, crinkled layers of screen, and No. 148, Air-Maze, has nine turns of screen with a cover of hardware cloth and a pressed steel, bell-shaped container. No. 145, AC Triplex, is shown in section in figure 9; No.



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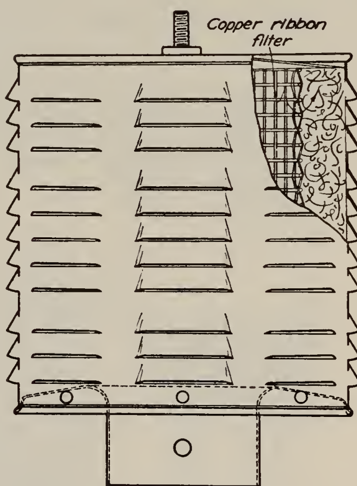

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Fig. 9.—No. 145, AC Triplex (section view); a loosely packed oily copper-ribbon filter, not self-washing. The coarser dust tends to fall into the oil at the bottom.

Fig. 10.—No. 90, AC (shown partly broken away); a loosely packed oily copper-ribbon filter.

90, AC, in figure 10. No. 154, AC for Graham-Paige, is a plain disk-shaped 2-in. thick filter of copper ribbon. No. 108, Winslow Down-Flo, is shown partly broken away in figure 11. No. 108*B* has a loosely packed fiber filter element of the same size as No. 108. No. 108*C* is like No. 108 but has fewer layers of screen in the filter element. The wool-filled oil reservoir at the top is to be replenished once a week. Oil from this reservoir and condensed vapors from the crankcase wash down the wire screen filter. Coarse dirt is thrown out by centrifugal

action before it reaches the filter. No. 144, Winslow, shown partly broken away in figure 12, is a modified form of Down-Flo designed for automobiles and trucks. The circular trough at the top distributes condensed crankcase vapors over the filter surface. Inlet of air is past inclined vanes at the bottom of the bell-shaped cover. No 123, Reed, is a plain, loosely packed filter of kinked steel wires filling a

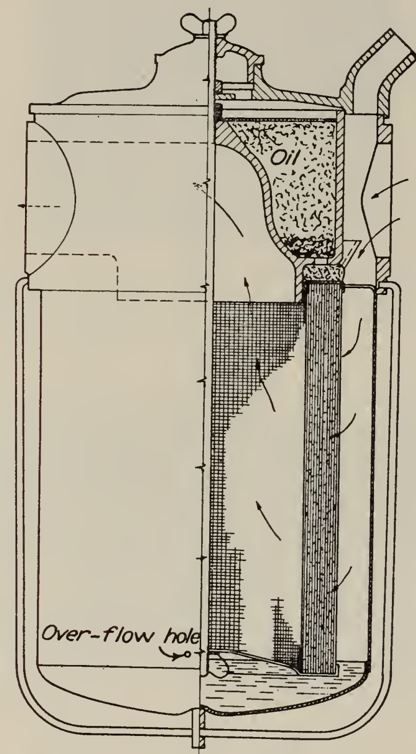

Fig. 11.—No. 108, Winslow Down-Flo (shown partly broken away). Oil in the wool-filled cistern at the top flows down over the screens of the filter. Crankcase vapors entering by way of the tube at right top assist in keeping the filter moist. Inclined vanes inside the top casting give a centrifugal action tending to throw the coarser dust against the oily walls of the shell.

cylindrical shell. Inlet is through a screen covering the bottom. No. 140, Case tractor type (not shown in fig. 7), is shown in section in figure 13 and in position in figure 14. Nos. 162 and 163, Earnest (fig. 15), are plain filters of loosely braided metal strip loosely packed in a shell readily removable from the cast portion by which connection is made to the carbureter. Nos. 168, 170, and 171, Ellis, and No. 167 Hinkle, are described in the next paragraph.

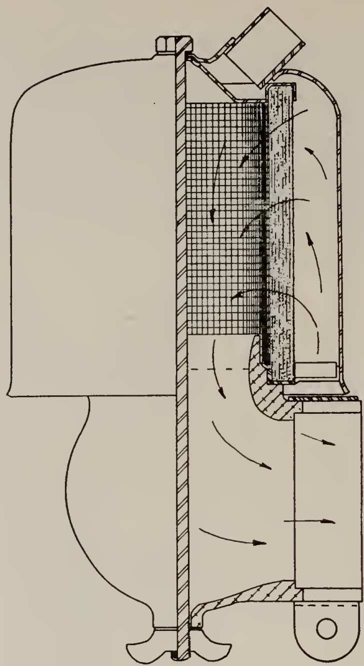

Fig. 12.—No. 144, Winslow (shown partly broken away). Centrifugal action is caused by inclined vanes in the air inlet to the bell-shaped cover. The cylindrical oily screen filter is washed down by crankcase vapors which condense in a circular trough at the top and are distributed over the filter and on the inside of the shell.

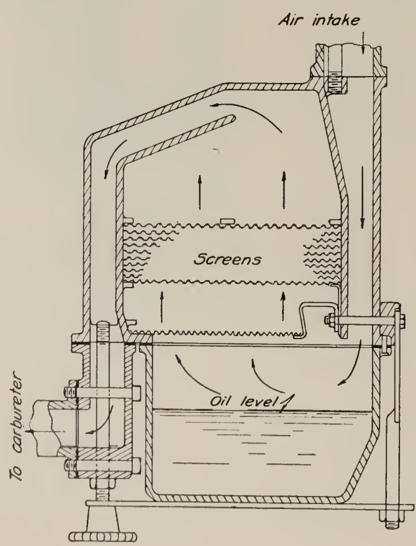

Fig. 13.—No. 140, Case tractor air cleaner (section view). The coarser dust tends to pass directly into the oil in the reservoir because of the inertia effect as the descending air stream abruptly changes direction just above the surface of the oil in the reservoir.

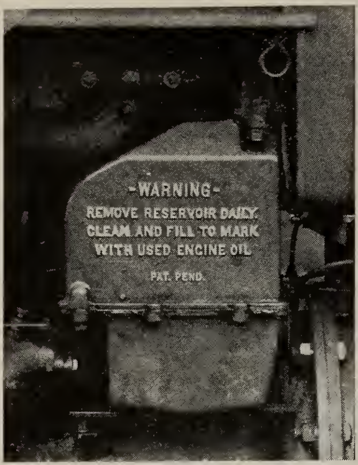

Fig. 14.—No. 140, Case, in position. This manufacturer evidently realizes that regular and frequent servicing is highly important. On many other air cleaners the directions are not so well marked.

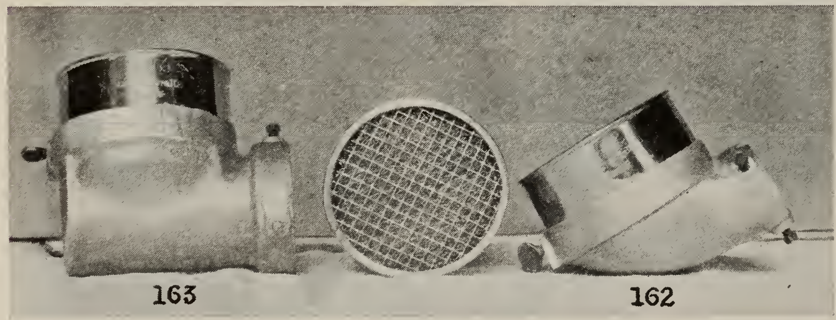

Fig. 15.—Nos. 163 and 162, Earnest, oily braided metal-ribbon filter cleaners for Buick and for Model A Ford, respectively. Filter element in the middle (same for both models shown) is made of noncorrosive materials.

Self-washing Oily Filter and Metal Surface Types.—Figure 16 shows self-washing oily filter and metal surface air cleaners. No. 168, Ellis, No. 167, Hinkle, No. 108, Winslow Down-Flo, and No. 144 Winslow, are described in the preceding paragraph. No. 84, Winslow Purifier, is designed for connection to crankcase side. The filter of organic fibers is washed down by condensed crankcase vapors. This cleaner also acts as oil-filler tube, crankcase ventilator, and breather cleaner. No. 153 and No. 141 (not shown), Miller; have a steel-wool filter filling the upper portion of the shell. An oil-lift operated by air pressure (vacuum from intake manifold) raises oil from the cup at the base and distrib-

utes it over the top of the filter. No. 155, R. & H., has a steel-wool filter filling the upper portion of the shell. Part of the entering air passing under a deflector is depended upon to cause oil from the cup at the base to bubble up and to be carried into the filter. No. 124*A*, Imperial, is shown partly broken away in figure 17. Nos. 130 and 132, Imperial (not shown in fig. 16), are the same in principle as No. 124*A*, but have

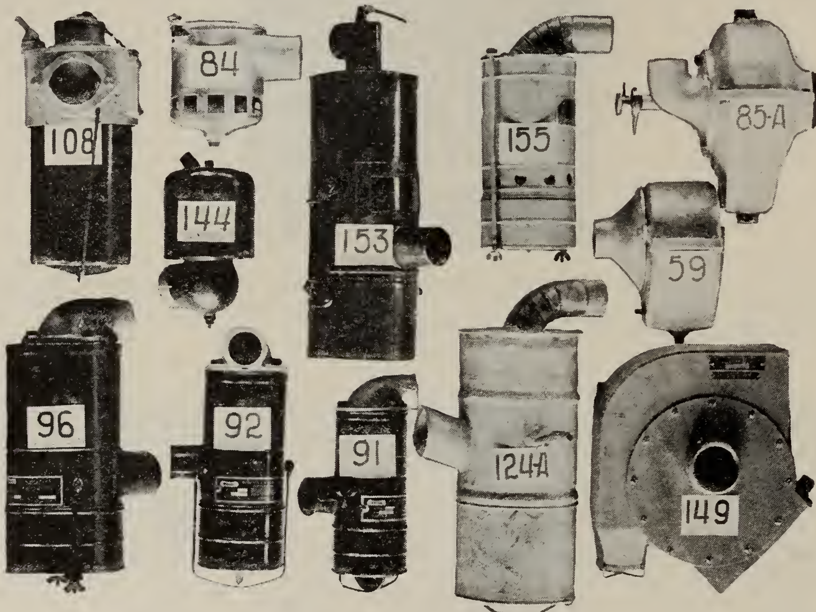

Fig. 16.—Self-washing oily filter and surface types. No. 124*A*, Imperial, steel wire (has oil lift connection to exhaust manifold) (see also figs. 17 and 18); Nos. 59 and 149, Midwest, steel plate (see also fig. 21); No. 153, Miller, steel-wool (has oil lift connection to intake manifold); No. 155, R. and H., steel-wool; No. 85*A*, Visco Rotary (English), steel plate (has ratchet device to rotate plate assembly); Nos. 91, 92, and 96, Vortox, oil centrifugal and kinked steel wire (see also fig. 19); No. 108, Winslow Down-Flo, dry centrifugal and wire screen (see also fig. 11); No. 84, Winslow Purifier, fiber (combination air cleaner, breather cleaner, oil filler tube, and crankcase ventilator); No. 144, Winslow, centrifugal and wire screen (see also fig. 12). *Not shown:* No. 168, 170, and 171, Ellis (fig. 23); No. 167, Hinkle (fig. 22); No. 140, Case, tractor (see figs. 13 and 14); Nos. 130 and 132, Imperial, somewhat similar to No. 124*A*; No. 141, Miller, similar to No. 153; No. 85, Visco Rotary, same as No. 85*A* except different plates; Nos. 93 and 115, Vortox, differing from No. 92 in size; Nos. 108*B* and 108*C*, Winslow Down-Flo, similar to No. 108.

the oil-lift unit and deflector shown in figure 18. Nos. 91, 92, and 96, and (not shown) Nos. 93 and 115, Vortox (formerly called Pomona), are similar in principle but differ in some of the dimensions. Figure 19 is representative of the Vortox line. The tangentially placed air inlet causes a whirl that throws much of the dust at once into contact

with the oily walls of the lower portion of the shell and of the oil cup and by a cyclonic action causes oil to spray up into the kinked wire filter element. The oil returns to the cup through channels provided. The cone in the oil cup is designed to increase the air-flow capacity by limiting the amount of oil sprayed up.

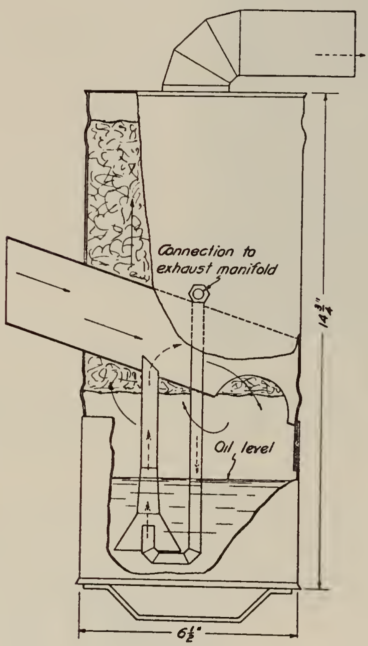

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Fig. 17.—No. 124*A*, Imperial (shown partly broken away). An exhaust pipe connection blows oil up for washing the kinked steel wire filter.

Fig. 18.—Oil lift unit and baffle of Nos. 130 and 132, Imperial. The purpose is to use inertia force to deposit coarse dust in the oil cup and (by the part on the left) to prevent too much oil from entering the filter.

No. 85*A*, Visco Rotary, an English cleaner used on military trucks in India, has perforated metal disks mounted on a shaft designed to be turned intermittently by a ratchet device connected with the accelerator pedal. Figure 20 shows the construction. No. 59, Midwest, is similar to the Visco Rotary, but the shaft is turned manually. No. 149, Midwest SD-5, has a rotor made up of plates having a special curvature. The accurately balanced rotor is designed to turn very slowly as accumulated dirt on the upper portions throws it out of balance. A valve in the base is designed to eject coarser particles of dry dust. Figure 21 shows some of the details.

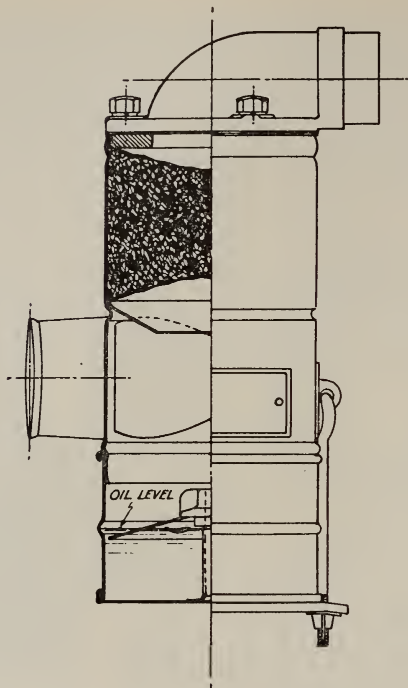

Fig. 19.—Nos. 91, 92, 93, 96, 115, Vortox (shown partly broken away). Air entering by the tangentially placed tube at the left throws the heavier dust against the oily walls of the cup and by a cyclonic effect sprays oil up into the kinked steel wire filter. The oil and dirt washed from the filter return to the cup by a special passage. The cone in the cup prevents excessive oil spray at high air speeds.

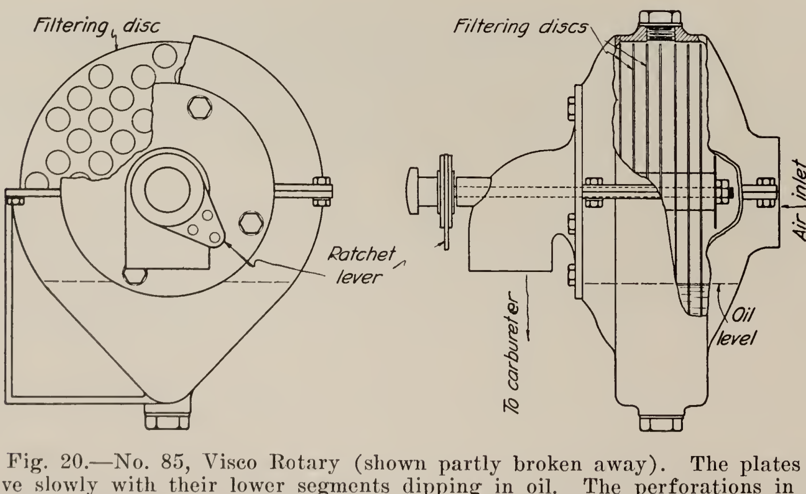

Fig. 20.—No. 85, Visco Rotary (shown partly broken away). The plates revolve slowly with their lower segments dipping in oil. The perforations in the plates are staggered. This cleaner is used on many military trucks in India. No. 85*A* has different plate perforations.

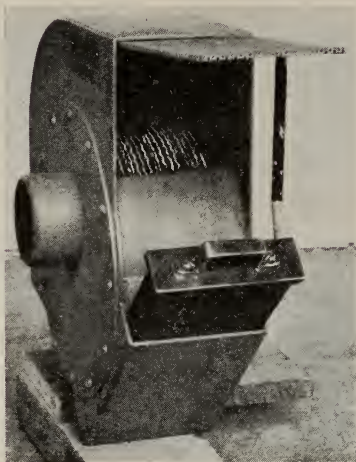

Fig. 21.—No. 149, Midwest SD-5. The rotor, the top edges of the curved plates of which are just visible within the cleaner, is designed to rotate slowly when made top-heavy by dust accumulation. Oil in the base washes off the dust.

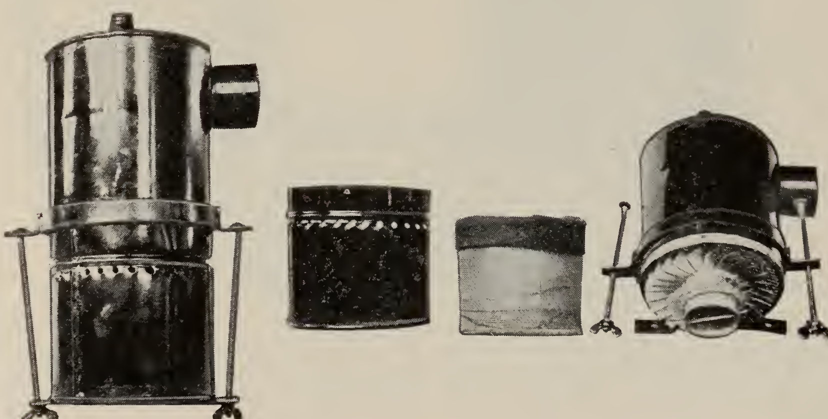

Fig. 22.—No. 167, Hinkle, shown assembled, *left*, and disassembled, *right*, a self-washing oily screen and metal shavings filter. The dusty air enters by a central tube extending from the top down into the oil cup and by a circle of small oblique openings near the top of the oil cup. Two sets of inclined vanes assist in distributing the oil over the screen filter in the oil cup and into the metal shavings filter in the upper portion of the cleaner.

Nos. 168, 170, and 171, Ellis, are self-washing steel-wool filters. The action is shown in figure 23. No. 167, Hinkle (fig. 22), is a self-washing screen and metal shavings filter. The dusty air enters by a central tube extending from the top down into the oil cup and by a circle of small oblique openings near the top of the oil cup. Within the oil cup and close to its walls is a hollow cylinder of screen (fig. 22, *right*, middle) having a flannel gasket and oil distributer at the top. The two sets of inclined vanes on the lower portion of the central tube assist in distributing the oil over the screen and into the shavings filter.

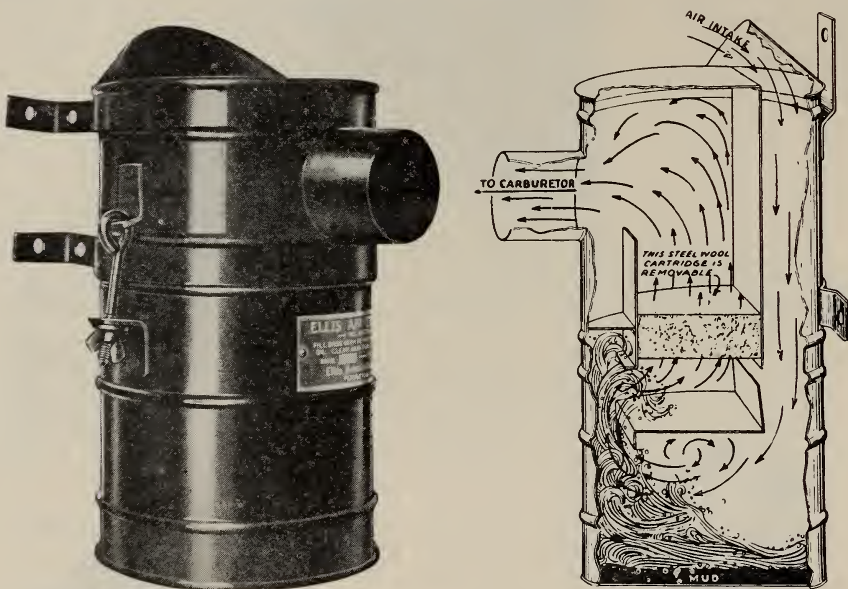

Fig. 23.—Nos. 168, 170, and 171, Ellis, self-washing cily steel-wool filter, shown assembled, *left*, and broken away, *right*.

Miscellaneous.—A group of miscellaneous oily types is shown in figure 24. Nos. 36 and 38, Bennett, combine a collecting-type dry centrifugal with a cylindrical closely packed oily fiber filter. Nos. 39 and 40, Donaldson Simplex, are cylindrical, closely packed, oily fiber filters in sheet metal shells. No. 113, Donaldson tractor type, has a removable filter element somewhat similar to that of No. 39 but the shell forms a collecting-type dry centrifugal. No. 78, Remington, has a removable cast-aluminum helicoid in a sheet-metal tube. A connection with the crankcase brings vapors to keep the surfaces oily. (See figure 25.) No. 79, Remington, has a fixed helicoid of sheet metal corrugated to increase the surface area.

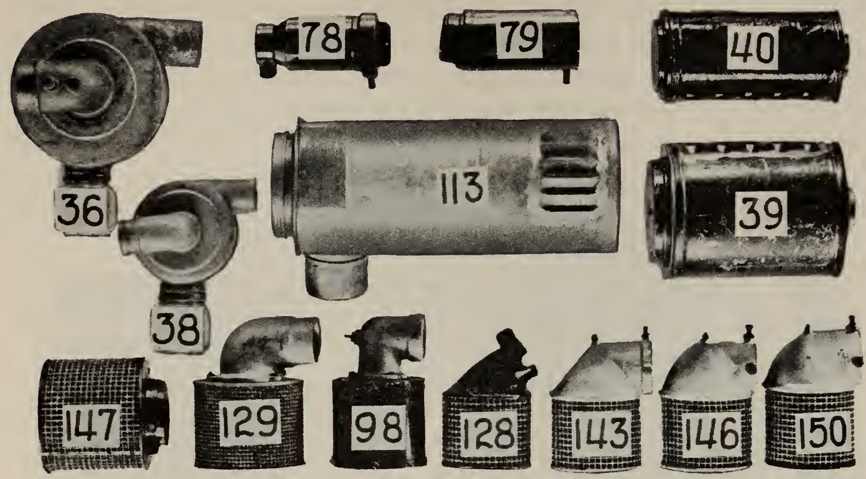

Fig. 24.—Miscellaneous oily types. Nos. 36 and 38, Bennett, dry centrifugal and closely packed fiber; No. 129, Bowden, for Buick, No. 147, same, for Chrysler 70, and Nos. 98, 128, 143, 146, and 150, same, for Model A Ford (see also fig. 26); Nos. 39 and 40, Donaldson Simplex closely packed fiber; No. 113, Donaldson (tractor), closely packed fiber; Nos. 78 and 79, Remington helicoidal surface (see also fig. 25). *Not shown:* No. 37, Bennett, similar to Nos. 36 and 38; Nos. 100 and 101, Bowden, similar to No. 129, and No. 161, similar to No. 150; No. 117, H–W Filtrator for Air, and No. 116, Winslow M, tractor types; Nos. 164, 173, and 174, C. R. C. oily surface type (see also figs. 28 and 29).

Note: Nos. 98 and 128 are obsolete.

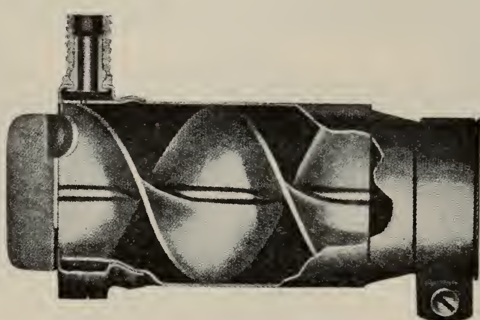

Fig. 25.—No. 78, Remington (shown partly broken away). The removable helicoid may be washed and dipped in oil. The crankcase connection (upper left) serves to help maintain oiliness of the surfaces.

Nos. 98, 100, 101, 128, 129, 143, 146, 147, and 150, Bowden, consist of piles of oil-saturated pasteboard rings cut in two forms placed alternating. The shapes are indicated in figure 26, *left*. Figure 26, *right,* shows a Bowden filter element after a test in which 10 grams of dust was sent into the cleaner. Note that the dust, as it is soaked by oil oozing out, collects mostly on the edges of the pasteboard rings.

Figure 27 shows No. 169, United 'Absolute,' a combination dry centrifugal ejector and oily kinked steel wire filter. This cleaner and No. 157, United, differ only in minor details. Louvers in the top and a tangentially placed air inlet near the top tend to eject the coarser dust through a slot at the side. The oily filter occupies the lower half of the shell. No. 164, C.R.C., Model No. 3 (not shown in fig. 24), is a low restriction, oily surface type air cleaner. The construction is

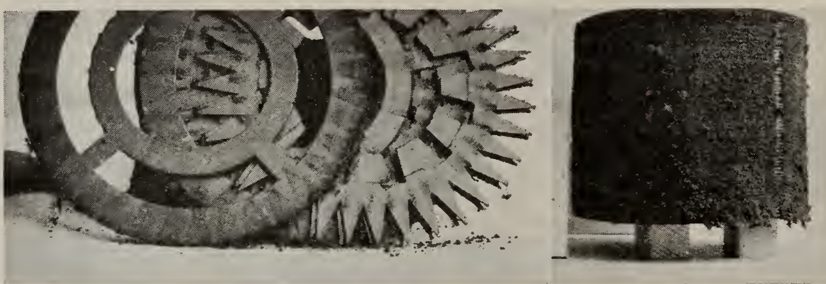

Fig. 26.—Bowden cleaners. *Left,* pasteboard rings typical of the two forms placed alternating in the pile that makes up the filter element in Nos. 98, 101, 128, 129, 143, 146, 147, 150, and 151. Note that some dust adheres to the flat surfaces. *Right,* filter element after a test in which 10 grams of dust entered the cleaner (No. 101). Note how the dust moistened by the oil that oozes out builds up on the edges of the pasteboards.

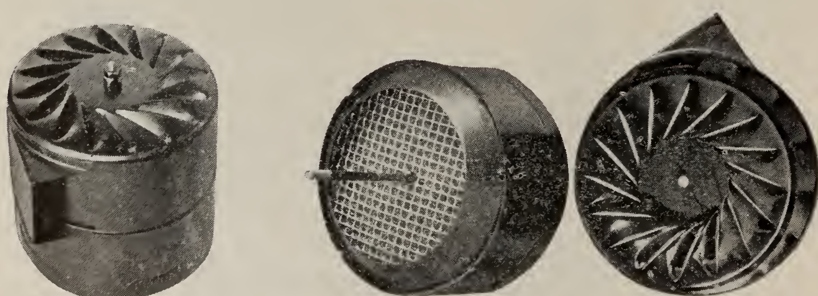

Fig. 27.—No. 169 United 'Absolute,' shown assembled, *left,* and disassembled, *right,* is a combination of an ejecting type dry centrifugal (due to louvres at the top and tangentially placed inlet at left) and a plain oily kinked steel wire filter. No. 157, United, is similar to No. 169 but differs in a few details. (Reflections in the part on the extreme right make the figure somewhat misleading.)

shown in figures 28 and 29. No. 165, C.R.C. Model No. 2*A*, is a smaller model of the same type. The operation of these cleaners is shown in figure 29. Primary cleaning is by contact with the surface of one baffle and the oil in the reservoir as the air passes downward from the inlet. Secondary cleaning is by contact with a set of five curved

baffles which separate the air rising toward the outlet into thin sheets. Nos. 173 and 174, C.R.C., are externally like No. 165 but have more plates and felts and have these assembled in a cartridge unit readily removable for cleaning and reoiling.

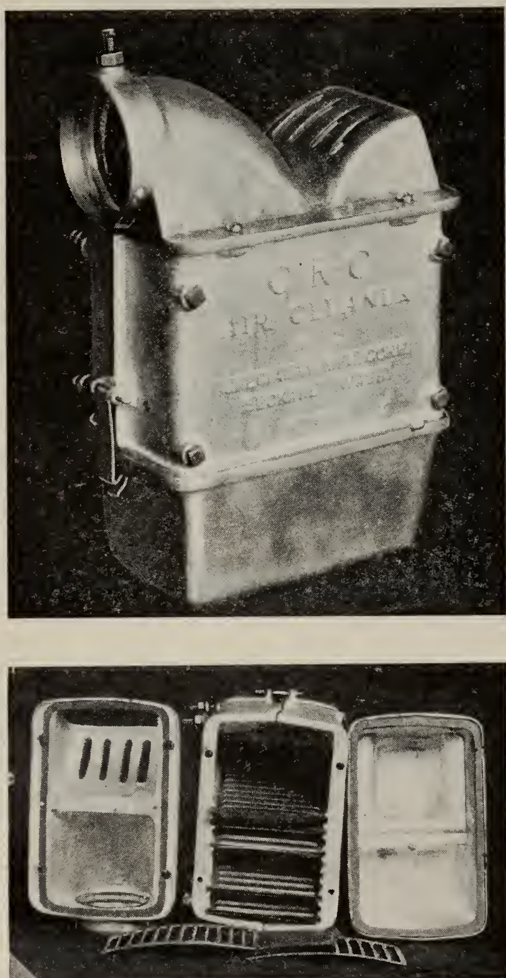

Fig. 28.—No. 164, C.R.C., Model No. 3, low-restriction, oily surface type air cleaner (received too late to include in group photograph). *Upper,* assembled. *Lower,* disassembled to show placing of baffles in middle portion. Primary cleaning is by contact with surface of one baffle and of oil in reservoir as air stream passes downward and turns toward the outlet; secondary cleaning is by contact with a set of five curved baffles which separate the rising air stream into thin sheets. A baffle (disassembled) appears in foreground. No. 165, Model 2–A, and Nos. 173 and 174, Models 2–6 sp. and 2–8 sp., respectively, are smaller sizes. Nos. 173 and 174 have the cleaning elements assembled in removable cartridge form.

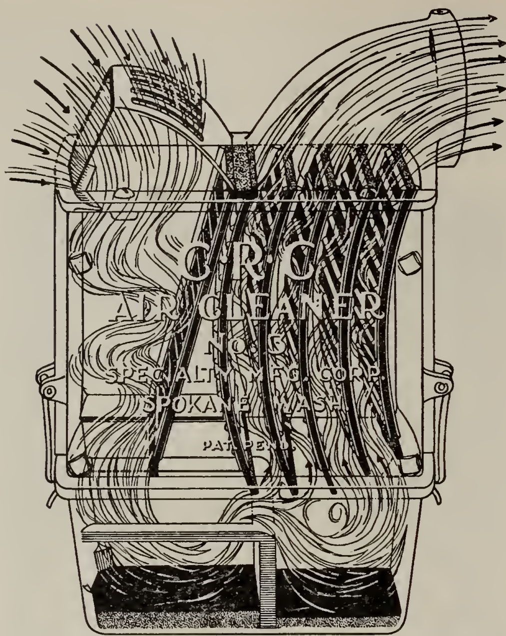

Fig. 29.—Nos. 164 and 165, C.R.C., phantom view showing arrangement of baffles and direction of air currents.

THE IDEAL AIR CLEANER

The characteristics required in the ideal air cleaner are (1) efficiency in separating dust from air, (2) little restriction (often called choking or vacuum effect), (3) small size, (4) infrequent need for servicing, (5) simplicity in design and construction, (6) freedom from troubles, (7) ability to muffle carbureter noises and to prevent ignition of gasoline from backfires, (8) neatness, sturdiness, durability, and low cost.

An inefficient air cleaner has no right to a place under the hood of a motor vehicle. From the point of view of the user its only excuse for existence lies in its ability to remove dust from air. If it fails in this most important respect, excellence in all other points counts for nothing. Road performance casually observed by the car owner or operator usually can afford no means of determining with any degree of accuracy whether the air cleaner in use is efficient or otherwise. The engines of most modern motor vehicles are so well designed and are built of such good materials and our highways in general are so nearly dustless that under ordinary conditions engine wear is slow and the useful life fairly satisfactory even if no provision is made for

protection against dust. Hence not infrequently an inefficient type of air cleaner, found as regular equipment on a motor vehicle, may, after serving its purpose as a salesman's 'talking point,' be apparently successful simply because it never encounters severe dust conditions. The presence of such air cleaners breeds a false sense of security in the car owner. When the machine is operated for an appreciable length of time over roads where volcanic ash abounds or in such places as some parts of the Imperial Valley, the engine quickly shows abnormal wear. Then the inefficient air cleaner is revealed in its true character and usually gives way to a cleaner able to take out the dust.

Next to efficiency in importance is the restriction effect (often called vacuum effect, or choking effect). If this effect is large, carbureter action may be interfered with, and loss of power and inefficient use of fuel may result. In an extreme case, the restriction, unless the carbureter can compensate for it, may cause so much choking that raw gasoline may wash the lubricating oil from the cylinder walls and permit metal to metal contact, with resultant rapid wear and, possibly, scoring. During the last year (1929), because of a general rise in road speeds, the designs of cleaners marketed have shown a marked trend toward very slight restriction, so that carbureter action might not be interfered with even at racing speeds. In some of these new cleaners the designers have sacrificed efficiency to secure a negligibly small restriction. In some other cleaners they have succeeded in securing high efficiency without undue restriction.

Usually space under the hood of an automobile is at a premium; hence the smaller the cleaner that can do its work satisfactorily, the more acceptable it will be. Also the simpler its construction and the less it is burdened with moving parts and connections to exhaust or to intake manifolds, the more readily will the engine designer give it a place.

Some automobile manufacturers have been reported as insisting that no air cleaner will be satisfactory to include as standard equipment on their product if it requires any attention or servicing. This demand, if strictly adhered to, would bar all air cleaners, since all require some attention. No cleaner now on the market can be installed and then forgotten, and still under all circumstances, month after month and year after year, afford satisfactory dust protection and not interfere with carbureter action. How the various types of cleaners behave in use and what factors determine the frequency of servicing required are discussed later (pp. 32 to 43). It seems absurd to require regular periodic attention and servicing for the several parts of the

lubrication system, the tires, the battery, the oil filter, etc., yet refuse to allow any servicing for so important an accessory as the air cleaner. Some of the best cleaners can do an excellent job under normal dust and running conditions for upwards of a year without attention; but all cleaners efficient enough to be worthy of the name should be given some care at least as often as the oil filter (once each 1,000 to 10,000 miles). This servicing should be regarded as payment of the premium on the engine's life insurance. When a truck or automobile equipped with a good but insufficiently serviced air cleaner is used in extremely dusty conditions, the expenses for time out, engine repairs, and early replacement are liable to total so large that the job may net the user of the machine a loss instead of a profit Many a power farming venture has failed almost wholly because of the carelessness that, among other things, allowed the tractor air cleaner to be forgotten.

Many air cleaners effectively muffle carbureter noises. Some also undoubtedly serve to reduce the danger of gasoline being ignited by backfires. The principle involved is the same as that of the Davy safety lamp, formerly much used by coal miners to prevent explosions when inflammable gases came into contact with the flames of ordinary candles or of wick lamps. In the safety lamp the flame was enclosed in a cage of fine mesh copper wire screen. The gases would catch fire inside the cage but the fire would not be propagated to the outside because the wires would absorb the heat from the burning gases as they passed through the screen. In a similar manner many modern air cleaners chill the burning gases of a backfire and reduce their temperature below that which would ignite vapors of gasoline (from leaky carbureters, tubes, and connections) and so reduce the hazard. Cleaners other than screen type may also have this property. The prime essentials are that the individual air inlet passages shall be very small and the materials capable of absorbing heat readily. Tests of the ability of air cleaners to reduce the fire hazard form no part of the work here reported. The Underwriters' Laboratories, 207 East Ohio Street, Chicago, Illinois, are reported as having made a few such tests.

PERFORMANCE CHARACTERISTICS OF VARIOUS TYPES OF AIR CLEANERS

Apparently the perfect air cleaner has not yet been invented. Nearly all of those on the market have at least one point of excellence, though in some cases that point may be of minor importance. It is hoped that the following general discussion of types and their more

important characteristics may enable the builder and the user of motor vehicles to judge with a fair degree of accuracy how closely any given cleaner approximates the ideal requirements. The laboratory tests of efficiency and restriction reported in table 3 will facilitate a fairly close estimate as to whether a given cleaner will serve only a few hundreds of miles or many thousands under normal conditions before it will lose its efficiency or build up too large a restriction effect. The cleaners listed may be identified by reference to the data given in table 1 and figures 1 to 29 inclusive. Explanation of the methods by which the data of table 3 were obtained is given on pages 47 to 54, and descriptions of the cleaners appear on pages 4 to 26.

Plain Dry Filters.—If the material is loosely woven or packed, plain dry filters may stop practically 100 per cent of the dust at first, but may later release that previously caught and allow it to pass on into the engine. If, on the other hand, the material is felted or very closely woven, it may continue indefinitely to stop practically all the dust; but, as more and more dust is caught, the restriction may increase to such an extent that loss of engine power may cause the driver to remove the air cleaner. This has often occurred, especially when fog or oily vapors have reached the filter. Cement dust seems to have a marked tendency to clog such filters. If the surface area of a felt filter is large for the rate of air flow and if the spacing leaves sufficient room between parts, the rate of increase of restriction and resulting loss of power will be slow and the service more satisfactory. Dry felt filters are slightly less efficient when new; they require a small amount of dust to fill up the larger pores in order to develop their full efficiency. Felt made of frowsy material and having only a small admixture of wool is liable to be lumpy and unsatisfactory for air filters. Filters of such material will show lower dust separation efficiency and, especially after long continued use, higher restriction than good woolen felt.

Filters made of sponge rubber about ¾ inch thick have been used to some extent as air cleaners. The efficiency is very high and the restriction not excessive. Two such cleaners used upwards of two years on passenger cars in a road test at Davis, California, gave excellent protection and showed less rapid deterioration than might have been expected for rubber used under such adverse conditions (high temperature and the presence of oily vapors). They were serviced annually by washing and rinsing in water.

If filter elements of felt or cloth must be taken out and dusted or washed either in water or in gasoline, holes are liable to be made

in the material, particularly if the surface is unprotected (as by a screen). Such filters have been found so full of holes that the efficiency of dust separation, instead of being nearly 100 per cent as at first, was reduced to about 50 per cent. If a dry felt filter is washed in oily gasoline, the oil remaining tends to make the restriction increase more rapidly.

Plain Oily Filters of Organic Fibers, Not Self-washing.—If sufficiently thick and of loosely packed material, plain oily filters of organic fibers show efficiencies well above 90 per cent and in some models satisfactorily low restriction. If they are washed with gasoline, dried, and reoiled at proper intervals, these good qualities are maintained. If the cleaner is not serviced, the fibers (or meshes) of the filter becomes heavily coated with dust, especially along the paths of least resistance through the filter. When all the oil on these fibers has been absorbed the restriction usually does not rise excessively, but the oncoming dust and sand wear off the encrusted dust from the fibers and eventually may polish them clean, leaving small dry tunnels through the filter. Thereafter only the coarsest dust and a small percentage of the fine will be stopped. This type of cleaner is, however, easily serviced, excels in simplicity and small size, and does not greatly interfere with carbureter action even when neglected, unless insects, chaff, or leaves in appreciable quantity get in. A coarse screen over the inlet may obviate this difficulty.

If the oily fibrous material is closely packed, the cleaner is likely to maintain high efficiency but have higher and higher restriction as dust is taken in, causing too rich a mixture, unless a balanced-tube carbureter is used. As the restriction increases the filter unit may be forced out of its usual position, leaving passages between it and the walls of the container.

Oily Wire Screen Filters, Not Self-washing.—Such filters are usually made of insufficient thickness to stop more than 30 to 50 per cent of the average dust; but, as ordinarily constructed, they offer very little restriction because of their extreme looseness or openness. For this same reason their capacity for holding oil is very small, being somewhat less than that of the loosest of curled-hair filters and about one-twelfth that of pasteboard-type cleaners of the same size. Hence they need washing and reoiling more frequently, except when used on some of the old-model machines in which the space under the hood may be covered with sufficient oil spray to keep the wire screens moist. If not reoiled frequently, this type speedily loses nearly all its power to separate any but the particles that are larger than the

meshes of the screen. It should be remembered in this connection that the great bulk of the dust which an air cleaner is called upon to eliminate will pass through a 325-mesh-per-inch screen.

Oily Metal Ribbon and Kinked Wire Filters, Not Self-washing.—These filters are usually intermediate, as to efficiency, restriction, and frequency of servicing required, between oily curled hair (or other organic fiber) loosely packed and loose oily screens. The thinner and looser the filter the lower the efficiency and the more frequent the need for servicing, but the smaller the restriction effect. Steel-wool usually has characteristics between kinked steel wire and curled hair.

Oily Pasteboard-Type Cleaners.—Oily pasteboard type cleaners vary in efficiency from about 70 to 95 per cent or better, depending principally upon the thinness of the pasteboard and the kind and amount of oil used. If the pasteboard is thinner than about $1/32$ inch, accumulating dust may raise the restriction and cleaning may be required oftener than once each 5,000 miles. If thicker than about $3/32$-inch, the efficiency is materially reduced. This type differs from the oily types previously mentioned in that the pasteboard itself acts as reservoir for several ounces of oil, which oozes out as needed to moisten the dust. An English cleaner using oil-saturated wood chips as the filter material is somewhat similar to the pasteboard type both as to efficiency and mode of operation but is probably not so easy to clean.

Caution: After oily filters, not self-washing, such as AC (copper ribbon), AC Triplex, Air-Maze, Bennett (oily fiber), Bowden, Donaldson (oily fiber), Earnest, National, and United 'Absolute,' are washed in gasoline or kerosene, they should be *dried thoroughly* before reoiling, or too much of the oil will drain off. The same thing happens if flushing oil or very dilute old oil is used. Reoiling should be by submerging the filter element; not by sprinkling a few drops from an oil can.

Self-washing Oily Filters.—Self-washing oily filters are in use on many modern tractors, on some trucks and busses, and, in cases where dust conditions are severe, as substitute equipment on automobiles. The chief reason for this selection is the possibility of securing high efficiency with constant and not too high restriction and with extraordinary capacity for handling dust. Disadvantages usually present in this type are relatively large size and the need of being placed in the vertical position. Self-washing oily filters, whether of organic fibers, kinked wires, metal strip, or woven or expanded metal screens, and self-washing oily surface cleaners, maintain their original effi-

ciency and restriction practically constant as long as the washing fluid (usually oil) is doing its work. In some makes of cleaners the washing action is very vigorous and effective; in others it is weak and inadequate.

Certain troubles are possible in some cleaners of this type. If the oil must be pumped or otherwise lifted in order to reach and wash the filter, the pumping device may become clogged; or, if there is a moving part, it may wear and become inoperative. If centrifugal action is depended upon to carry up the oil, and if too high viscosity of the oil results from cold or from evaporation of volatile components, the action may cease. Or, if oil of too high original viscosity is used, the lifting action may not take place at all. If, however, too light an oil (kerosene or flushing oil, for example) is used, some may entrain and carry dirt with the air to the carbureter. For most self-washing cleaners there is a rather wide range of viscosity of oil, throughout which washing will take place satisfactorily. In any self-washing oily filter, action will cease when the whole volume of oil in the reservoir is absorbed by the dust caught. Thereafter the cleaner will act much as a plain oily filter, the limitations then being as before mentioned for that type. The length of time the cleaner will serve before all the oil is absorbed depends upon (1) the volume and volatility of the oil, (2) the average rate at which the engine draws air through, (3) the average temperature and dustiness of the air, (4) the position of the air intake, and (5) whether any oil goes over to the carbureter. Since all of these may vary widely, no definite time can be specified. A cleaner of this type has been known to function satisfactorily on an automobile for a year without any servicing. On the other hand, when used under extremely dusty conditions on a tractor, the same type has caught so much dust that it required daily emptying of dirt and dirty oil from the reservoir.

The efficiency of self-washing oily filter cleaners may be as low as 70 or 80 per cent or as high as 97 to 99. If the filter is too loose or too thin, or the material unevenly placed, the efficiency is lower. Manufacturers are often tempted to put out thin filters because of the low restriction effects. Another factor markedly affecting efficiency is whether much of the dust is disposed of at once in the oil cup or whether all must be caught by the filter proper.

In some self-washing cleaners the oil pumped or otherwise lifted flows by gravity over and down the filter element. In others a crankcase ventilator connection brings vapors of water and of oil and oily spray to the filter to supplement a slow flow of oil from a cistern

designed to be filled whenever new oil is added to that in the crank-case. In both these types the rate of oil flow, though sufficient to keep the filter moist, may be so slow as to afford little or no washing action. In some cases of poor design the oil or vapors may moisten only one part instead of the whole filter.

In contrast with the two types just mentioned are the types in which a vigorous spray or splash of oil thoroughly washes down the dirt caught in the filter element. In the first two types the filter element itself might need periodic cleaning; in the last type periodic removal of dirt from the oil reservoir and replenishing of the oil would suffice. Proper size of cleaner for the given engine is important for this type. Dust sometimes collects on the inside surfaces of the air inlet tubes of certain self-washing oily filter type cleaners and may clog the passage unless it is cleaned out periodically. This is due to the tendency of oil to creep over metal surfaces. Some plain oily filters, not self-washing, may be affected similarly.

Deterioration in Oily Fiber Filters.—The fibers, if loosely packed, may wear and break after long use because of vibration or may rearrange themselves so as to leave relatively large passages through which the air may pass uncleansed. In some cases, the oil itself may possibly cause or hasten disintegration of the fibers. Loose pieces from a disintegrating filter may clog carbureter passages. For similar reasons steel-wool may cause trouble if substituted for kinked hard-drawn steel wire or for copper ribbon. Such troubles concerning the last two materials mentioned have never been brought to the author's attention, except where the materials were too loosely packed; but corrosion troubles have been reported in cases where the dissimilar metals chosen for filter and container have set up electrolytic action when moisture was present.

Oily Metal-Plate Type Cleaners.—Metal-plate cleaners are capable of very rugged construction and are not adversely affected by extremes of air temperature. They are usually similar to the oily screen type as to efficiency, but as a rule show somewhat higher, though constant, restriction. In some cases they are made self-washing by rotating circular plates with the lower segments dipping in oil.

This type may be made of the required efficiency by using a sufficient number of plates or by adding wire screens between adjacent plates. In one make of this type the plates are formed to a certain curvature so that inertia (centrifugal) effects aid in bringing the dust particles into contact with the oily surfaces, especially at high air speeds. When the metal plates are rotated at very slow speeds the

washing is usually satisfactory and no oil entrains, but if the rotation is too rapid, drops of dirty oil are liable to go over to the carbureter.

A cleaner of somewhat similar type consists of a helicoid of metal fixed in a tube through which the air is made to pass. A tube coming from the crankcase acts as a ventilator and brings vapors of oil and of water to moisten the surfaces of the cleaner. Unless adequate provision is made to prevent it, the condensed oil and water vapors will flow along the inside surfaces of cleaners of this type, carrying the dirt along into the carbureter.

Another modification of the oily metal-plate type is in use in Germany and elsewhere in Europe. The dusty air is made to pass through a filter consisting of a mass of oily thimbles (made by cutting off short pieces of metal tubing). The efficiency is good if sufficient depth of filter is used and the thimbles are frequently washed and reoiled. The restriction is not excessive if the proper area of filter is chosen, but the device is bulky.

Inertia-Type Cleaners.—These cleaners (almost all of which are dry centrifugal; see fig. 7) are as a rule unable to handle satisfactorily anything except the coarser dust particles. Designers sometimes raise the efficiency by restricting the area of the inlet passages where the whirling motion is imparted; but when this is done the restriction is increased and may become prohibitively high at high car speeds. Further, at low speeds and consequent slow flow of air through the cleaner, the power to separate the dust particles is almost entirely lost. Experience has shown repeatedly that cleaners of this type do not furnish adequate protection under severe dust conditions. This is illustrated by the case shown in figure 30. A new 1928 six-cylindered automobile in use by the California Highway Commission between Oroville and a road construction camp about 16 miles out had run only 3,478 miles when the engine was found so badly worn that the cylinders had to be rebored and 0.015-inch oversize pistons put in. The air cleaner supplied as regular equipment on this machine was a dry centrifugal without rotor and without dust ejector slots. The expectation of the designer of the cleaner evidently was that the separated dust would fall out by gravity through the same openings by which the dusty air entered. After each hundred miles of use of the machine in question it was found necessary to take apart the carbureter and its connections and remove the accumulated dirt. One such cleaning-out yielded the dirt shown in the beaker in figure 30. It weighed 99.48 grams (3½ ounces) net dry. This amount represents not the whole amount of dust that entered the cleaner during the 100

miles, but only the portion that passed through the cleaner and stopped in the carbureter and connections instead of going on into the engine. A self-washing oily filter type cleaner was substituted and no further trouble was reported in the year following.

As further evidence of the inability of dry centrifugal-type air cleaners to afford adequate protection against dust and undue wear, the data given in table 2 on solid impurities (other than carbon) removed by crankcase oil filters may be cited. At the odometer readings and dates specified the oil filters on the several machines were removed and carefully cut open, and the oil, dirt, and filter cloth were

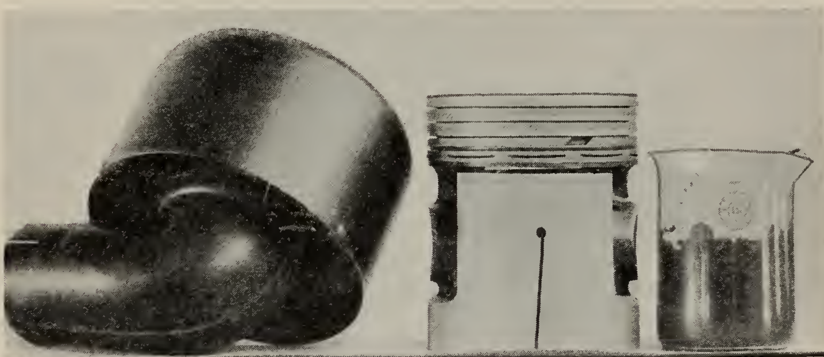

Fig. 30.—Dry centrifugals do not protect sufficiently. Air cleaner and piston from a 1928 six-cylindered automobile used by the California Highway Commission near Oroville. After 3,478 miles 0.015-inch over-size pistons were necessary. Note gaps between rings and grooves. The dust in the beaker was removed from carbureter and connecting tubes after 100 miles of use.

incinerated. The total ash from each filter and the equivalent ash per 1,000 miles may reasonably be regarded as significant indications of the wear that occurred in the engines during the service of the particular filter. As would be expected, the wear and consequently the ash per thousand miles is highest when a machine is new and the rubbing surfaces are not yet fully smoothed. Analyses (made by H. W. Allinger) show that the ash is composed principally of iron oxide and road dust with smaller amounts of oxides of copper, lead, tin, and other metals.

Of the cars listed all but No. 3 were used exclusively in the same subtropical region and same kind of service. No. 3 had a mid-summer transcontinental trip of 10,025 out of a total of 12,728 miles. Probably three-fourths of its total mileage was on earth roads and under summer conditions. It will be noted that 'eastern' oils were used in all of the machines and that very frequent draining was not practiced in any of

them. All the oils except one were of medium viscosity. Although car No. 1 had the advantage of heavy oil, its record of relative wear as indicated by ash per thousand miles is more than twice the average of the other three machines. Since all the drivers are known to be skilled and careful, there seems to be no reason to doubt that the differences in wear as indicated by the ash resulted primarily from the difference in efficiencies of the two types of air cleaners used.

TABLE 2

Solids Taken Out by Engine Crankcase Oil Filters

Car No.	Car Make and Model	Air cleaner, make and type	Oil filter Make	Oil filter No.	Date put on	Date taken off	Odometer reading On	Odometer reading Off	Miles used	Ash Total, grams	Ash Per 1,000 miles, grams
1*	Buick, 27-20, coach	AC, dry centrifugal	AC, B1	1	Oct. 15 1927	Feb. 25 1929	0	8,344	8,344	34.7	4.16
				2	Feb. 25 1929	Oct. 15 1929	8,344	13,782	5,438	24.1	4.43
				Totals and weighted average					*13,782*	*58.8*	*4.26*
2†	Buick, 28-26S, club coupe	Bowden, oily pasteboard	AC, B1	1	Oct. 15 1927	Apr. 23 1928	0	5,000	5,000	14.4	2.88
				2	Apr. 23 1928	Sept. 6 1929	5,000	16,043	11,043	17.3	1.57
				Totals and weighted average					*16,043*	*31.7*	*1.97*
3‡	Buick, 28-20, coach	Bowden, oily pasteboard	AC, B1	1	Oct. 27 1927	Apr. 18 1928	0	1,851	1,851	14.5	7.84
				2	Apr. 19 1928	July 26 1928	1,851	12,728	10,877	15.4	1.41
				3	July 26 1928	Jan. 29 1930	12,728	20,876	8,148	13.2	1.62
				Totals and weighted average					*20,876*	*43.1*	*2.03*
4¶	Dodge, Victory Six sedan, 1928	Bowden, oily pasteboard	Purolator, SA2	1	 1928	Feb. 19 1929	0	3,081	3,081	10.7	3.47
				2	Feb. 19 1929	May 22 1929	3,081	6,224	3,142	3.7	1.18
				3	May 22 1929	Oct. 18 1929	6,224	12,470	6,246	10.5	1.68
				Totals and weighted average					*12,470*	*24.9*	*2.00*

* Car No. 1 was used at Davis, California, and vicinity; the oil used was Pennzoil heavy; crankcase was drained at 779 and at 8,344 miles.

† Car No. 2 was used at Davis, California, and vicinity; the oil used was Pennzoil extra medium; crankcase was drained at about each 1,000 miles.

‡ Car No. 3 was used at Davis, California, and vicinity and 10,025 miles transcontinental; the oil used was mostly Pennzoil extra medium; crankcase was drained at 600, 1,817, 7,000, 12,000 and 20,876 miles.

¶ Car No. 4 was used at Davis, California, and vicinity; the oil used was Valvoline medium; crankcase was drained at 250 and 9,500 miles.

Contrary to common opinion, dry centrifugal-type cleaners offer very considerable restriction especially at high car speeds (see tables 4 and 5 and figs. 36, 37, and 38). The length of time since the last servicing will, however, usually have little effect on the restriction. Though cleaners of this type do not require very frequent servicing, they do need occasional attention to maintain even their low efficiency.

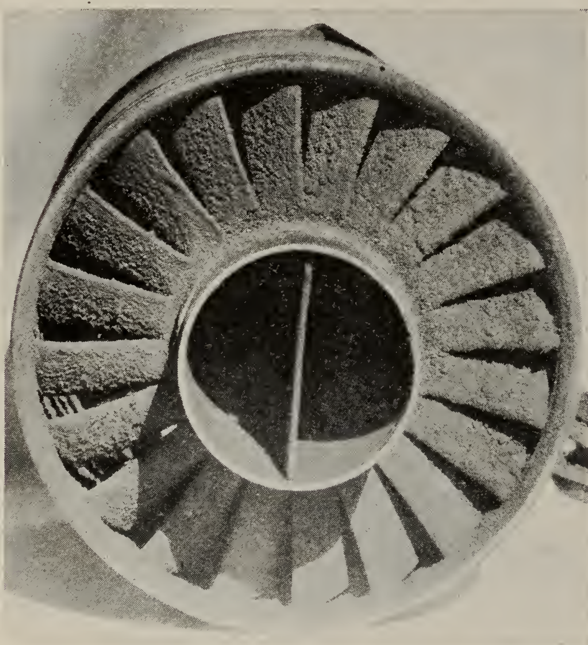

Fig. 31.—Even a dry centrifugal air cleaner needs some attention. After about 20,000 miles use the vanes may become loaded with oily dust and need washing off. The partition across the outlet is designed to take the whirling motion from the air before it enters the carbureter.

If there are dust-outlet slots, they may become clogged with oily dirt, the bodies of insects, or bits of chaff or leaves. The vanes may become heavily coated with dirt (fig. 31) and become less effective. The moving parts, if any, may become worn or loaded down with accumulations of dust and oily vapors so that their action may be impaired or cease entirely. If gas from the exhaust manifold is used to eject the separated dust, carbon will accumulate in the venturi throat, upon the action of which the functioning of such ejectors depends. If, however, an engine is in good condition and adjustment, with little carbon in the exhaust, the throat of such a cleaner should not require cleaning out oftener than once in four to six months of normal operation.

The air leaving a dry centrifugal cleaner may still have considerable whirling motion when it enters the carbureter. This may interfere with carbureter action in some machines at certain engine speeds. Usually cleaners of this type have a device for straightening the air flow. The partition across the outlet of the cleaner shown in figure 31 is for this purpose.

Inertia-type cleaners using the blast from the radiator fan as an auxiliary are found to have the limitations common to the inertia type and in addition are handicapped in that they must necessarily be placed where the dust concentration is greater than at some other places under the same hood.[3] Their small servicing requirements and simplicity gave them some popularity a few years ago, but they have now practically disappeared. See "Effect of Position of Air Intake," p. 43.)

Water-Type Cleaners.—These cleaners are still used on a few tractors but are in general too heavy and bulky for use on road vehicles. They have become unpopular even for tractors chiefly on account of (1) the large amount of care and attention required; (2) the tendency, especially of some constructions, to get out of order; (3) the danger of freezing; and (4) the danger, under certain circumstances, of water going over into the carbureter. Some makes have given excellent service on tractors. These good records result from extra-large water capacity, robust construction of interior parts, adequate provision against clogging by chaff, leaves, and insects, and care in placing the air intake so as to avoid the bulk of the dust. Some recent work reported by the United States Bureau of Standards[4] shows that moistening the air entering the carbureter reduces detonation (knocking) and makes for smoother running, but may reduce power by as much as 8 or 9 per cent in extreme cases.

Combinations.—Combinations of several types in one cleaner are often attempted, and sometimes two cleaners are used in series. Generally in such cases an inertia type is placed ahead of a filter with the idea of lessening the work of the latter and so increasing the time between servicings. Placing two cleaners in series on an automobile engine is in the main unsatisfactory because the combined restriction of the cleaners and their tubular connections is too high and because the cost and space requirement are larger. The use of more than one

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[3] Hoffman, A. H. Efficiency test of radiator fan type air cleaners. Jour. Soc. Auto. Engin. 21:82–86. 6 figs. 1927.

[4] Brooks, D. B. Horsepower correction for atmospheric humidity. Jour. Soc. Auto. Engin. 25:277–283. 8 figs. 1929.

principle of dust separation is, however, found in several of the most satisfactory cleaners. In such cases skillful designers have combined and proportioned the several parts so as to avoid excessive restriction and secure good dust separation.

EFFECT OF THE POSITION OF THE AIR INTAKE

Tests have shown that not all possible positions for the air intake to the carbureters of automobiles,[5] trucks, and tractors[6] are equally dusty. In one case the time between servicings of the air cleaner on a certain small tractor was increased from one day to ten days by simply taking in the air through a standpipe extending 2 feet above the regular low intake position. Long tubular connections or 'periscopes,' used for drawing cleaner air from higher levels, are undesirable on automobiles and trucks because the inertia of the long air column tends to make the engine sluggish when the throttle is opened suddenly. Also the added restriction is more detrimental where wide variations in speed and engine load are the rule, as in road vehicles. High intake pipes are found on a number of late-model tractors. Their use increases the effectiveness of the air cleaning equipment and is unobjectionable except in orchard work and the like (where headroom is limited). Flexible metal tubes are notoriously leaky unless kept well taped and shellacked. Air leaks between air cleaner and carbureter may admit much dust. They should be closed by the use of friction tape securely fastened.

The direction of the air inlet with reference to the direction of the fan blast is also of considerable importance. This is shown by a three-year test made of the dust caught by a self-washing oily filter type cleaner on a Dodge touring car.[7] During one year the air inlet faced the blast from the radiator fan; during the next two years it faced in the reverse direction, as in figure 32. The dust caught per mile of travel during the first year averaged 3.5 times as much as that during the next two years. In a laboratory test using equal amounts of a standard dust and the two tubes shown in figure 33, the ratio of dust taken in was 2.35 to 1.

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[5] Hoffman, A. H. Best location for carbureter intake. Jour. Soc. Auto. Engin. 16:501–502. 5 figs. 1925.

[6] Hoffman, A. H. Mapping the dust concentration around small tractors. Agr. Engin. 7:12–13. 4 figs. 1926.

[7] Hoffman, A. H. Does your carbureter air inlet face forwards? Agr. Engin. 8:13, 2 figs. 1927.

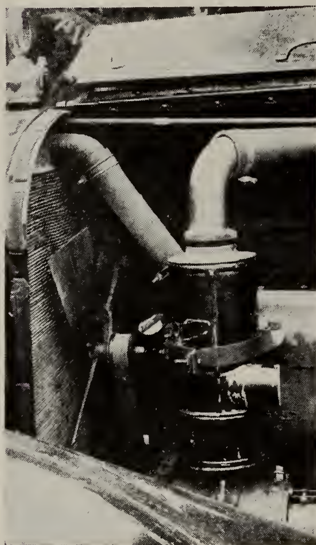

Fig. 32.—The air inlet should not face the fan blast. In a road test lasting three years it was found that 3.5 times as much dust per mile was caught when the inlet faced forward as when in the position shown.

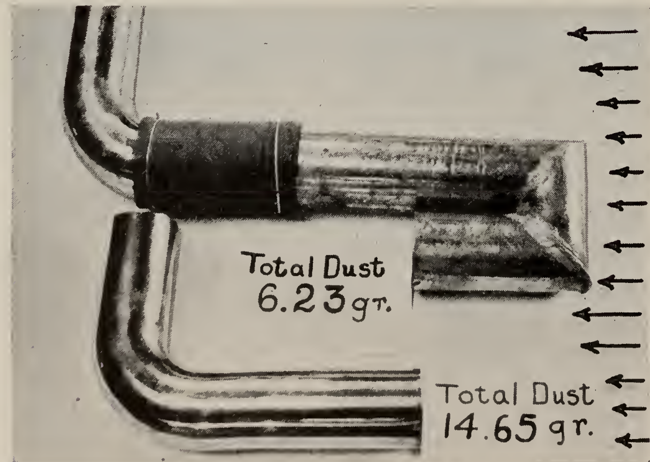

Fig. 33.—The effect of the direction of the inlet. In two laboratory tests, alike except that in one the inlet faced the air stream (coming from the right) as below, while in the other, the return-bend above, it faced down stream, the ratio of dust taken in was 2.35 to 1.

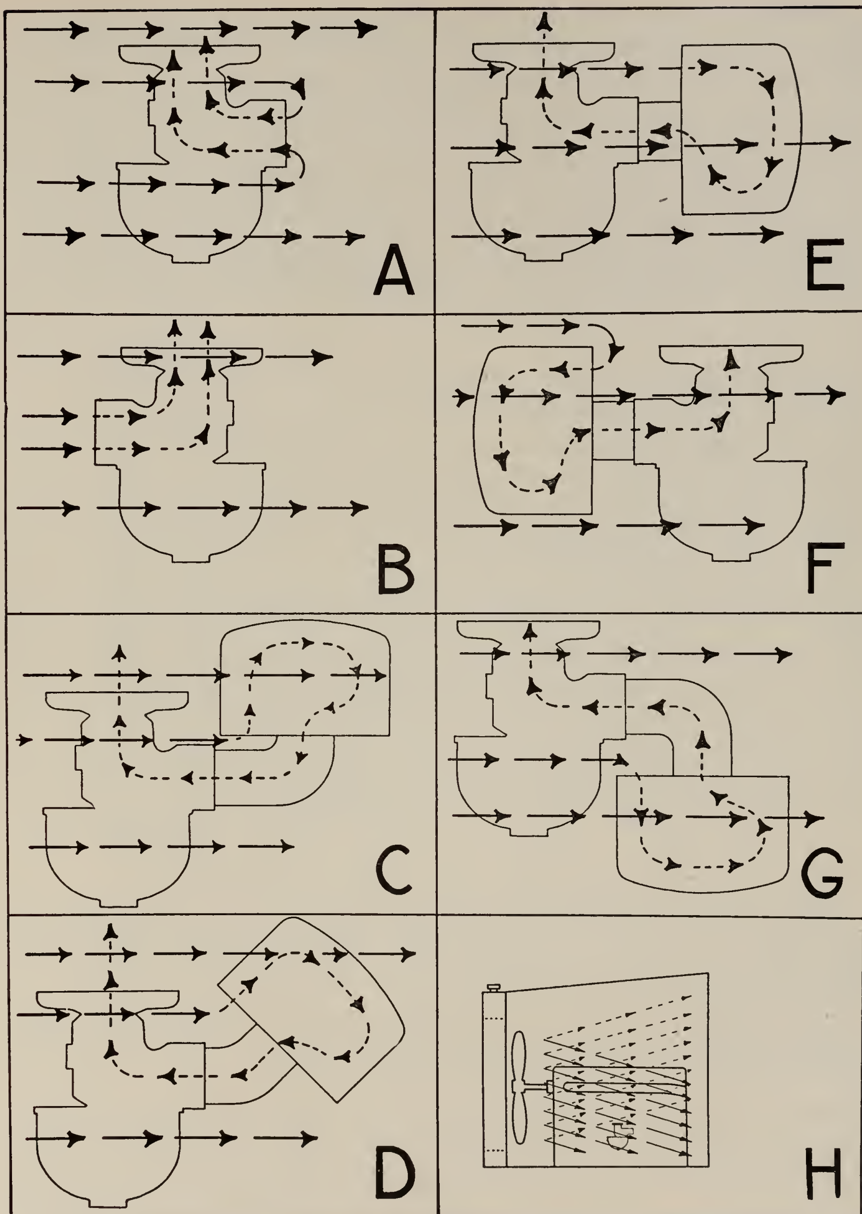

Fig. 34.—Carbureter and air cleaner air-inlet placings. If no air cleaner is used, *A* is preferable to *B*. If an ejecting type dry centrifugal (without rotor) is used, it should be placed with its inlet facing away from the radiator fan as in *F* rather than as in *D* or *E*. Usually *C* is preferable to *G*, because coarse dirt might fall into a cleaner placed as in *G*. The radiator fan tends to throw the air-stream upward on one side of the engine block and downward on the opposite side as shown at *H*. If in the upward stream, *C* would tend to take in more dirt than G.

Figure 34 illustrates various possibilities of carbureter and air-cleaner inlet placing and shows why different amounts of dust are taken in. If no air cleaner is to be used, arrangement *A* is preferable to *B*. If an ordinary dry centrifugal with ejector slots and without rotor is used, it should usually be placed as in *F*. If the cleaner is placed as in *E* it becomes in effect a 'dust scoop' and more dust might enter the carbureter than would go in if the cleaner were left off. This arrangement is found in one air cleaner designed for a certain late-model car. Arrangement *D* is probably little, if any, better than *E*.

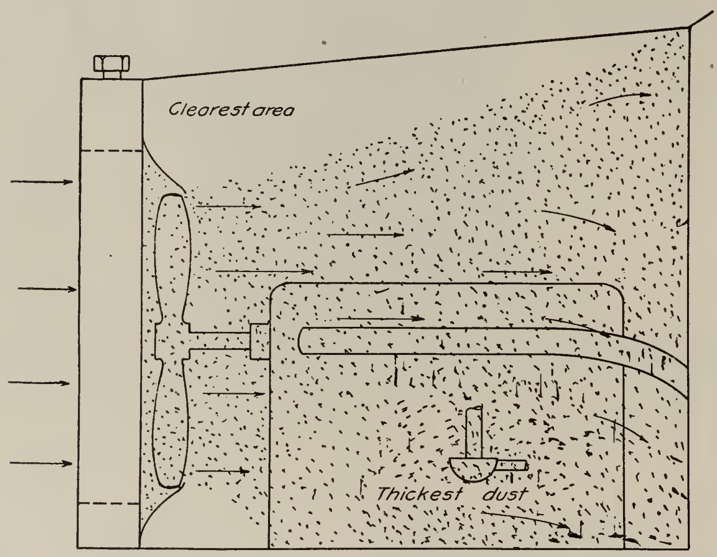

Fig. 35.—Dust distribution under the hood when the fan is shrouded and the belt tight. Not all spaces are equally dusty. Often the dustiest place is where the carbureter is located. In V-type engines it may be feasible to take the carbureter air from the clearest area.

Note: This figure is suggestive only. For methods of mapping dust concentrations under the hood, see reference in footnote 5, p. 43.

Whether *C* or *G* is preferable depends upon which side of the engine the air inlet is placed. Usually *G* is to be avoided. As indicated in *H*, the radiator fan throws the air stream somewhat upward on the side of the machine on which the fan blades rise and downward where the blades descend. If the air inlet is placed on the descending side, arrangement *C* may possibly be preferable to *F*. It should be remembered also in this connection that objects in the air stream, for example, starting motors, spark coils, etc., act as partially effective dust shields for the spaces immediately back of them.

Cleaners that do not have a protecting shell, such as the National and some models of Bowden and of Air-Maze, are also considerably affected by their position with respect to the fan blast. The blast striking an unprotected side of one of these cleaners quickly removes the oil from the filter material on that side and drives in the dust. This results in lowered efficiency and earlier need for servicing. When such cleaners are placed in the horizontal position, usually the end plate serves as a protecting screen. If they must be placed in the vertical position, a cylindrical or half-cylindrical shield may be used with advantage.

Figure 35 shows the dust distribution under the hood of an automobile when the fan is shrouded (as in the figure) or when the blades run very close to the radiator and when there are louvres in the sides of the hood. As indicated, the thickest dust is found where the carbureter is usually located. In automobiles the air cleaner is nevertheless generally attached directly to the carbureter to avoid long tubular connections, which tend to make engine acceleration sluggish. In some engines, for example V-types, it is feasible to draw the air from the clearest area just back of the upper portion of the radiator. This has been done in one or two makes of machines. Because the air required by the carbureter is only a small fraction of that drawn through the radiator by the fan, the presence of the carbureter air-inlet at any given place under the hood does not greatly affect the dust distribution.

TESTS OF AIR CLEANER EFFICIENCY AND RESTRICTION

Road Tests of Dust-Separation Efficiency.—Road tests of the efficiency of air cleaners on automobiles and trucks are difficult to make because of many variable factors, such as wind, weather, and soil conditions, which prevent accurate determinations. The effectiveness of air cleaners to reduce engine wear can, however, be tested by weighing and measuring piston rings and other principal wearing parts before and after definite periods (at least 10,000 miles) of regular use of the machines, some equipped with air cleaners and other unequipped. Such tests, to be of value, must be repeated several times on different makes of machines, and the results averaged. Unless great care is taken, especially with regard to the placing of the air inlets, such tests may be very misleading. Other factors may also obscure the effect under study, for example, if in one machine heavy

oil is used and in another light, if one crankcase is drained frequently and another infrequently, if one machine has a crankcase oil filter and another none, if one is driven by a careful man and another by one who closes the choker and then forgets it.

A number of such wear tests have been made. They show that thorough removal of dust from the air entering the carbureter sometimes reduces wear to about three-fourths what it would be in the unprotected engine when a normal amount of dust is present, and sometimes to as low as one-eighth, when dust conditions are extreme. As would be expected, the effect is greater for the top piston rings than for any other wearing part.

Laboratory Tests of Dust-Separation Efficiency.—Laboratory tests made under uniform controlled conditions and using a standardized dust give in general more dependable and satisfactory results without too great expenditure of time. A method found satisfactory is to draw air at measured rate through the cleaner undergoing test and a so-called 'absolute cleaner' in series with it, and to brush out a weighed amount of the standard dust into a fine cloud and cause it to enter the air stream going into the cleaner. The filter element (good-quality felt) in the 'absolute cleaner' catches practically all of the dust not caught by the cleaner undergoing test. Drying and weighing this filter before and after gives data for calculation of the efficiency, or percentage of dust stopped, in the cleaner undergoing test.

The Character of the Standard Dust.—Dust used for testing air cleaners should be as nearly as possible like that which the cleaner must handle in actual service. The dust entering air cleaners in service is exceedingly fine. It is so fine that ordinarily upward of 90 per cent of it will pass the finest obtainable standard wire screen (325 meshes per inch). Hence screen methods cannot produce a dust that will give a dry centrifugal type cleaner a proper test. Many tests have been made in which very coarse material was used as the 'dust.' Tests with such material do not determine what the cleaners will actually do in service. No doubt such tests account for claims of high efficiency sometimes made for cleaners that experience shows do not effectively protect against dust. Some tests made at Davis of the floating and settling properties of dusts used for air-cleaner testing showed that the materials employed by four American manufacturers were from 2.7 to 5.4 times as easy for dry centrifugals to remove from air as the 'No. 3 standard' dust used in the tests reported in table 3.

One dust used by a foreign air cleaner company proved to be nearly 17 times as easy. If such coarse and heavy material is used, the tests will indicate in a measure what the cleaner in question will do with the small percentage of similar coarse material that must be handled when, as occasionally happens, an automobile is caught in a sandstorm in the desert; but it tells nothing as to what the cleaner will do with the large percentage of very fine dust in the air during the same sandstorm or with the dust that floats over our roads during the summer months.

By air-flotation methods dust of satisfactory fineness can be secured from field soils. However, the mere fact that a dust is air-floated does not necessarily mean that it is sufficiently fine. Even gravel will be carried along by the air if the rate of air flow is high enough. If in making dust for testing purposes the air stream carrying the powdered soil to the settling tanks is kept slow enough, the dust obtained will be of fineness comparable with that of the dust that remains in the air for a minute or more after a vehicle has passed on an earth road. It is much safer in testing to use very fine dust. If an air cleaner can handle such dust efficiently, it may generally be assumed to be able to take care of coarser material also. On the other hand, the fact that a cleaner shows high efficiency when tested with coarse dust is no assurance whatever that it will be able to take out the fine. Apparatus for making dust of proper fineness for air-cleaner testing has been described.[8]

The Restriction Effect of Air Cleaners.—The restriction (also called choking or vacuum effect) is measured by the difference of levels in a U-shaped tube of glass (called a manometer) partly filled with water, one end of which is open to the air while the other is connected so as to have the same air pressure as is in the outlet of the air cleaner. Thus connected, the manometer reading will be a measure of the combined restriction effect of the air cleaner and whatever high intake tubes, etc., may be connected to the inlet. If in such case the restriction effect of the cleaner alone is to be measured, one side of the manometer, instead of being left open to the air, must be connected to the inlet tube where it joins the cleaner proper. The water-level reading will of course vary with the rate of air flow through the cleaner, and this in turn will depend upon the load and speed of the engine. Hence the rate of air flow must be known if the number of inches of water representing the restriction effect is to have significance.

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[8] Hoffman, A. H. A comparison of dusts used for testing air cleaner efficiency, Hilgardia 5:17–33. 10 figs. 1930.

TABLE 3

SUMMARY OF LABORATORY TESTS

No.	Name, model, and type (Descriptions are given in table 1, pp. 5 to 12)	Efficiency approximate		Restriction, approximate in. of water at 50 cu. ft. air per min.		Oil going over to carbureter during test?	Approximate servicing requirements in normal California use on automobile engine of appropriate size[b]
		Clean, per cent	After use,[a] per cent	Clean	After use[a]		
36	Bennett, dry centrifugal and oily fiber filter, 6 1/2 in.	98	99	1 3/4	7	No	Wash and reoil; 3,000 miles.
37	Bennett, dry centrifugal and oily fiber filter, 6 in.	98	99	5 9/16	10	No	Wash and reoil; 3,000 miles.
39	Donaldson Simplex, 6-in. oily fiber filter	99	99	15/16	2	No	Wash and reoil; 5,000 miles.
40	Donaldson Simplex, 4-in. oily fiber filter	99	99	1 7/16	3	No	Wash and reoil; 5,000 miles.
42	Gordon, 10-in. rubber sponge filter	99	99	3 1/8	3 3/8	....	Wash in water; 5,000 miles.
59	Midwest, T-1, self-washing metal plate	92	92	3/4	3/4	Trace	Remove dirt; new oil; 10,000 miles.
65-1	AC, ('26), dry centrifugal collector	45	45	1 1/2	1 1/2	....	Remove dirt; clean; 10,000 miles.
66	Eddy (Spencer), inertia and dry filter	80	80	1 1/4	1 1/2	....	Clean; 10,000 miles.
74	Zenith, Type II, dry centrifugal and felt filter	99	100−	1 5/16	1 9/16	....	Clean; 5,000 miles.
75	Tillotson, OW 500, centrifugal collector and filter	37	37	1 7/8	2	....	Remove dirt; clean; 10,000 miles.
76	Tillotson, OW 560, centrifugal collector	28	28	15/16	15/16	....	Remove dirt; clean; 10,000 miles.
77	Air-Maze, 3 ST, oily screen filter	60	45	3/16	3/16	No	Clean and reoil; 2,000 miles.
78	Remington, removable oily helicoid	50	50[c]	1 3/4	1 3/4	Yes	Clean; 2,000 miles.
79	Remington, fixed oily helicoid	57	57[c]	1 3/4	1 3/4	Yes	Clean; 2,000 miles.
84	Winslow Purifier, self-washing filter	93[d]	93+[d]	2 7/16	3	No	Clean by spilling oil when filling crankcase.
85	Visco Rotary, revolving oily plates	76[d]	76[d]	1	1	Yes	Remove dirt; new oil; 10,000 miles.
87	Protectomotor, C-4, dry felt filter	98	99	1 1/8	1 3/4	....	Blow out dirt (airhose); 10,000 miles.
88	AC, dry centrifugal ejector	20	....	1 7/8	1 7/8	....	Clean; 20,000 miles.
90	AC, oily copper strip filter	50	48	11/16	11/16	No	Clean and reoil; 2,000 miles.
91	Vortox, 270, self-washing filter	96	96	7 5/16	7 5/16	No	Clean oil cup; refill; 10,000 miles.[b]
92	Vortox, 850, self-washing filter	97	97	5 1/8	5 1/8	No	Clean oil cup; refill; 10,000 miles.[b]
93	Vortox, 750, self-washing filter	92	92	2 3/8	2 3/8	No	Clean oil cup; refill; 10,000 miles.[b]
94	United, for Chrysler, dry centrifugal	13[e]	13[e]	3	3	....	Clean; 20,000 miles.
95	United, for Chrysler (with shield), dry centrifugal	6[f]	6[f]	1 13/16	1 13/16	....	Clean; 20,000 miles.

TABLE 3—(Continued)

No.	Name, model, and type (Descriptions are given in table 1, pp. 5 to 12)	Efficiency approximate		Restriction, approximate in. of water at 50 cu. ft. air per min.		Oil going over to carbureter during test?	Approximate servicing requirements in normal California use on automobile engine of appropriate size[b]
		Clean, per cent	After use,[a] per cent	Clean	After use[a]		
96	Vortox, 1000, self-washing filter	[g]	[g] See road test p. 57.			No	Clean oil cup; refill; 10,000 miles.[b]
97	Donaldson, for Model A Ford, oily fiber filter	90	99	2 1/4	4	No	Clean; reoil; 5,000 miles.
98	Bowden, for Model A Ford, thin oily pasteboard	77[d]	90[d]	2 9/16	3 15/16	No	Clean; reoil; 5,000 miles.
100	Bowden, thin oily pasteboard	68[d]	84[d]	1 3/8	3 5/16	No	Clean; reoil; 5,000 miles.
101	Bowden, thin oily pasteboard	70[d]	80[d]	1 1/16	2	No	Clean; reoil; 5,000 miles
108	Winslow Down-Flo, self-washing screen filter	90[d]	90[d]	3/4	3/4	No	Clean out; reoil; 10,000 miles.
108 *B*	Winslow Down-Flo, self-washing hair filter	85[d]	90[d]	3/4	7/8	Trace	Clean out; reoil; 10,000 miles.
108*C*	Winslow Down-Flo, self-washing screen filter	86[d]	86[d]	5/8	5/8	No	Clean out; reoil; 10,000 miles.
109	United, with rotor, dry centrifugal	68	68	2 1/2	2 1/2	....	Clean, inspect bearing; 20,000 miles.
110	United, "4½-in. horizontal," dry centrifugal, 4 slots	65[h]	65[h]	1 3/8	1 3/8	....	Clean; 20,000 miles.
111	Handy, dry centrifugal, 1 slot	56	56	1 3/4	1 3/4	....	Clean; 20,000 miles.
112	Handy, dry centrifugal, 1 slot	45	45	1 1/2	1 1/2	....	Clean; 20,000 miles.
113	Donaldson Twinplex, dry centrifugal and oily filter	93	95	1 3/4	1 7/8	No	Clean; reoil; daily (tractor)
114	Annis Air Filter, dry felt filter	98	100	1	2 1/2	....	Clean with brush or compressed air; 10,000 miles.
115	Vortox, 135, self-washing filter	93	93	4 13/16	4 13/16	No	Clean oil cup; refill; 20,000 miles.
116	Winslow, M, oily fiber filter	80	80	1/2	1/2	No	Clean oil cup; refill; daily (tractor).
117	H-W Filtrator For Air, oily fiber filter	85	85	1	1	No	Clean oil cup; refill; daily (tractor)
118	United, for Model A Ford, dry centrifugal, 4 slots	35[i]	35[i]	2 1/16	2 1/16	....	Clean; 20,000 miles.
119	Protectomotor, C-4, dry felt filter	99	100	3/4	3/4	....	Blow out dirt (air-hose), 10,000 miles.
122	Tillotson, Model X-1, dry centrifugal collector	35	35	15/16	15/16	....	Remove dirt; clean; 20,000 miles.
123	Reed, 6E1, oily wire filter	85	85	1/2	1/2	No	Clean; reoil; 3,000 miles.
124A	Imperial, self-washing filter	91	91	1 1/2	1 1/2	No	Clean oil cup; refill; 10,000 miles.[j]
125	National, for Model A Ford, oily hair filter	95	88	1 1/8	1 1/8	No	Clean; reoil; 5,000 miles.
128	Bowden, for Model A Ford, thick oily pasteboard	72	75	1 1/8	1 1/2	No	Clean; reoil; 8,000 miles.
129	Bowden, for Franklin, thick oily pasteboard	76	79	1	1 1/2	No	Clean; reoil; 8,000 miles.
130	Imperial, self-washing filter	98	98	3 1/2	4	Yes	Clean oil cup; refill; 10,000 miles.[b,j]

TABLE 3—(Continued)

No.	Name, model, and type (Descriptions are given in table 1, pp. 5 to 12)	Efficiency approximate		Restriction, approximate in. of water at 50 cu. ft. air per min.		Oil going over to carbureter during test?	Approximate servicing requirements in normal California use on automobile engine of appropriate size[b]
		Clean, per cent	After use,[a] per cent	Clean	After use[a]		
132	Imperial, self-washing filter	88	88	1	1¼	No	Clean oil cup; refill; 10,000 miles.[b j]
133	Gordon, 5-inch, dry felt filter	98	99	1⅛	9	....	Clean; 2,000 miles.
134	Gordon, 6-inch, dry felt filter	98	99	1 1/16	6	....	Clean; 2,000 miles.
135	Gordon, 8-inch, dry felt filter	98	99.9	15/16	5	....	Clean; 2,000 miles.
136	National, for Buick 28-20, oily hair filter	See No. 125		1	1	No	Clean; reoil; 5,000 miles.
138	Air-Maze, for Model A Ford, oily screen filter	See No. 77		1⅝	1⅝	No	Clean; reoil; 2,000 miles.
140	Case (tractor), self-washing oily screen filter	g	g	1	1	No	Clean reservoir; refill daily (tractor)[b]
141	Miller, self-washing oily filter	97	97	1	1	Yes	Clean oil cup; refill; 10,000 miles.[b]
143	Bowden, for Model A Ford, thick oily pasteboard	75	78	1½	1½	No	Clean; reoil; 5,000 miles.
144	Winslow, self-washing oily screen	No test; estimate 85-90		11/16	11/16	No	Clean out; reoil; 10,000 miles.
145	AC Triplex Heavy Duty, copper ribbon filter	90	85	1⅝	1⅝	No	Clean; reoil; 5,000 miles.[b]
146	Bowden, for Model A Ford, thick oily pasteboard	Road test only		1¾	....	No	Clean; reoil; 8,000 miles.
147	Bowden, for '30 Chrysler "70," thick oily pasteboard	Vacuum test only		7/16	....	No	Clean; reoil; 8,000 miles.
148	Air-Maze, for '30 Chrysler "70," oily screen filter	Vacuum test only; see No. 77		¼	....	No	Clean; reoil; 2,000 miles.
149	Midwest, SD-5, self-washing surface	70 to 95[k]	70 to 95[k]	⅝	⅝	l	Clean out reservoir; refill; 10,000 miles.
150	Bowden, for Model A Ford, thick oily pasteboard	See No. 143		2 1/16	....	No	Clean; reoil; 8,000 miles.
151	Morse, Type B (return bend), dry cloth filter	92	92	2 3/16	13	....	Clean, 1,000 miles.
152	Morse, Type A (return bend), dry cloth filter	93	93	2⅜	16	....	Clean, 1,000 miles.
153	Miller, self-washing oily filter	94	94	3 7/16	3 7/16	Trace	Clean out cup; refill; 10,000 miles.[b]
154	AC (off Graham-Paige), oily copper ribbon filter	55	40	⅛	⅛	No	Clean; reoil; 2,000 miles.
155	R & H, self-washing oily filter	93	93	3¼	3⅝	No	Clean out cup, refill; 10,000 miles.[b]
157	United, dry centrifugal and oily kinked wire filter	No standard test		15/16	15/16	No	Clean; reoil; 5,000 miles.
160	Annis, dry felt filter	97	100	⅜	⅜	....	Clean with brush or compressed air; 10,000 miles.
161	Bowden, for Model A Ford, thick oily pasteboard	82	84	2⅛	2⅛	No	Clean; reoil; 8,000 miles.
162	Earnest, Model F, oily braided metal ribbon filter	90	90	2¼	2 5/16	No	Clean; reoil; 5,000 miles.

TABLE 3—(Concluded)

No.	Name, model, and type (Descriptions are given in table 1, pp. 5 to 12)	Efficiency approximate		Restriction, approximate in. of water at 50 cu. ft. air per min.		Oil going over to carbureter during test?	Approximate servicing requirements in normal California use on automobile engine of appropriate size[b]
		Clean, per cent	After use,[a] per cent	Clean	After use[a]		
163	Earnest, Model C-3, oily braided metal ribbon filter	90	90	1	1⅛	No	Clean; reoil; 5,000 miles.
164	C. R. C., Model No. 3, oily surface type	[g]	[g]	13/16	13/16	No	Clean; reoil; 10,000 miles.
165	C. R. C., Model No. 2A, oily surface type	86	86	1¾	1¾	No	Clean; reoil; 10,000 miles.
167	Hinkle, self-washing oily filter	95	95	1¼	1¼	No	Remove dirt; new oil; 10,000 miles.
168	Ellis, Model A, self-washing oily filter	91	91	1 5/16	1¾	No	Remove dirt; new oil; 10,000 miles.
169	United Absolute, dry centrifugal and oily filter	87	87	7/16	½	Trace	Clean filter; reoil; 5,000 miles.
170	Ellis, Model A, self-washing oily filter	97	96	2⅝	2⅞	No	Remove dirt; wash filter; new oil; 10,000 miles.
171	Ellis, Model C ('combine type'), self-washing oily filter	98	97	2¼	2½	No	Remove dirt; wash filter; new oil; 10,000 miles.
173	C. R. C. 2-6 sp., oily surface type	93	93	3 3/16	3 3/16	Trace	Clean plates; reoil; 10,000 miles
174	C. R. C. 2-8 sp., oily surface type	92	92	2⅝	2⅝	No	Clean plates; reoil; 10,000 miles

[a] The dust used in this test is about equivalent to that taken in during 10,000 miles normal California road use.
[b] For trucks, servicing of air cleaner is normally required about 2 to 4 times as often as for automobiles; for tractors about 200 to 800 times as often as for automobiles.
[c] Water and oil brought as vapors from crankcase by ventilator connection wash dirt along into carbureter.
[d] Reported results of this cleaner in use indicate somewhat better efficiency than was shown in the short-time laboratory test.
[e] When placed with air inlet away from fan. With inlet towards fan more dust went to carbureter than if cleaner had been left off.
[f] When placed with axis vertical, shield towards fan.
[g] Testing apparatus too small to give this cleaner a proper test of efficiency. Reports of field use indicate that this cleaner affords adequate protection.
[h] Placed in position *F*, fig. 32.
[i] When placed as in *F*, fig. 32. It is less effective when placed as in *E* as designed, and may even act as a 'dust scoop', taking in more dust than the unprotected carbureter.
[j] Clean out exhaust connection about each 20,000 miles.
[k] Efficiency increases with higher air-flow rates.
[l] No oil going over unless rotor was turned at too high speed.

In table 3 the restriction given for each cleaner is for approximately 50 cu. ft. per minute of free air under standard conditions. This is about what an ordinary 25-hp., 4-cylinder gasoline engine requires when running at a speed of 1200 r.p.m. and carrying full load. It is also equivalent to about what is required in still air on a level road by a Buick Standard six coach at 38 miles per hour or by a Model A Ford coach at 42 miles per hour constant speed. The foregoing figures are only approximate. Temperature of the air and of the engine carbureter adjustment, spark advance, quality of the gasoline and of the oil used, are some of the many factors that affect the air requirements. In general the cleaners tested (tables 1 and 3) are of such sizes as the manufacturers considered suitable for the 25-hp., 4-cylinder engine on which the tests were made, though a few of the cleaners are obviously too large and a few too small. The dimensions of each cleaner tested are given in table 1.

Larger size in a cleaner, other things remaining the same, would tend to make the restriction effect smaller for the same rate of air flow, regardless of the type of cleaner. Larger size, within reasonable limits, would have no appreciable effect on the efficiency of plain filter type cleaners whether dry or oily, but would decrease the efficiency of cleaners that use the inertia principle either alone or in combination with some other principle. The efficiency of dry centrifugal cleaners (the most common form of the inertia type) is practically zero for the low air-flow rates that are present when an engine is idling.

The Results of the Laboratory Tests.—A summary of the results of laboratory tests made on the cleaners identified by the data given in table 1 and by figures 1 to 29 inclusive is given in table 3. Approximate efficiencies are given for two conditions: when the cleaner is new or freshly serviced, and at the end of a test in which a 10-gram sample of the 'No. 3 standard' dust has been fed in. Many road tests extending over a period of about six years have shown that the average automobile used throughout the year under normal conditions in California will take in an average of about 0.001 gram of dust per mile. This makes a 10-gram charge of dust equivalent to what would normally be taken in during 10,000 miles of road use. The laboratory tests were made with care in an endeavor to get a true picture of how the cleaner would behave in road use.

In a test involving many individual cleaners it is necessary, in order to finish within a reasonable time, to use considerably higher rates of dust feeding than those normally found on the road. For all

inertia-type cleaners and for most of the others tested it is believed that the high rates of dust feed made no appreciable difference in the efficiency. In a few cleaners, however, the construction and principles of operation are such that the high rate of dust feed was probably a handicap. This may have been the case with oily pasteboard-type cleaners and with cleaners that have a filter or other dust-catching surface designed to be kept oily by vapors brought from the crank-case through a breather connection. In the latter type evidently much less oil would be available for use in a laboratory test lasting an hour or less than in 5,000 or 10,000 miles of road use. In pasteboard type cleaners the oil held in the pasteboards oozes out slowly and saturates the on-coming dust as it arrives. The dust can easily be fed faster than the oil can come out to absorb it. On the other hand, where the oil does not soak in but is all held on the surfaces of metal strips, ribbons, wires, or plates, it is available to absorb dust as long as any is left, and therefore a high rate of dust feed would present little or no handicap. Reports of several road tests made by users of the paste-board type and the type in which moistening is maintained by crank-case vapors indicate somewhat higher efficiencies than were found in the short-time laboratory tests. On the other hand, the validity of the laboratory findings of low efficiency in dry centrifugal-type cleaners has been abundantly attested by the rapid wearing out of engines equipped with cleaners of that type and used under extremely dusty conditions. A typical example has already been cited (fig. 30).

In measuring the restriction effect in the laboratory tests the utmost care was exercised to make sure that the connections used did not introduce an appreciable error. Large errors can easily enter through the use of adapters of improper shapes and sizes and because of incorrect construction and placing of the piezometer rings by which connection is made between the air in the cleaner inlet and outlet and that in the two legs of the U-tube manometer. In making comparisons of the restriction effects of several cleaners it is important to note whether all have elbows in the outlet tubes. In some cases the restriction resulting from the elbow is as much as that from all the rest of the cleaner.

The data of servicing requirements given in the last column of table 3 are based principally on the results of the laboratory tests of efficiency and restriction and on a careful study of each cleaner's construction and mode of operation, but also in part, in most cases, on the results of road tests. In some cases the gradually lowering efficiency is what determines how soon servicing may become press-

ingly necessary; in some it is the gradually rising restriction; in others both conditions may be found. The reasons for the wide range of mileages between servicings may be found in "Characteristics of Various Types of Cleaners" (pp. 32 to 43). The mileage between servicings given in the last column of table 3 are for *normal California road conditions.* This means about 90 per cent of the mileage on paving. Therefore these mileages should be regarded as the maximum under very favorable conditions. When vehicles are used mainly on dirt roads, servicing must be much more frequent.

Road Tests of Restriction.—Road tests were made on a number of the more prominent cleaners on the market to determine the variation in restriction at different car speeds. For the first set of these tests the cleaners were applied in succession to the carbureter of a Buick, Model 28–20, standard coach, and for the second set to that of a Model A Ford coach. In the first set attachment to the carbureter inlet was through a short straight piece of tubing, except in the case of a few of the large cleaners. For these latter it was necessary to use and make correction for the tubular connections listed at the bottom of table 4. In every case the cleaner undergoing test was mounted under the closed hood. All the tests were run on the same nearly level paved highway at times of calm or low wind velocity. The restriction effect was read on an open U-tube manometer carried in the car and suitably connected to the short tube by which the cleaners were connected to the carbureter inlet.

The results of the test using the Buick (table 4 and figs. 36 and 37) are the averages of a number of readings at each speed, half of them taken in the outgoing direction and the other half when returning over the same course, so as to eliminate the effects of wind and slight grades. The curves of figures 36 and 37 are drawn smoothly from the data given in table 4. Certain irregularities that may be noted probably result from the slight differences in grade in the road. These effects were probably negligible at the highest speeds. The results show that at and below 40 miles per hour none of the cleaners tested offers enough restriction when clean or freshly serviced to interfere seriously with the action of most types of carbureters. At higher speeds, however, some of the cleaners, especially those that have centrifugal action, increase in restriction very rapidly. This in part results from the fact that to set air into whirling motion requires energy, which in this case is obtained by a drop in air pressure. The 'air-straightener' placed in the outlet tube of some cleaners to prevent carbureter action being interfered with by the whirl serves also to restore some of the lost pressure.

TABLE 4

Road Tests* of Air Cleaner Restriction Made on a Buick 28–20 Coach

Cleaner		Outlet elbow?	Miles per hour					Remarks
			20	30	40	50	60	
			Restriction, in. water					
No.†	Make and type							
88	AC, dry centrifugal ejector, off Buick 28-20	No	0.15	0.4	2.5	4.4	7.7	
65-A	AC, dry centrifugal collector, off Buick '26	No	0.15	1.0	1.8	4.1	6.5	Old style with cup
90	AC, oily copper ribbon	No	0.10	0.3	1.2	2.0	2.9	
77	Air-Maze, oily screen	No	0.04	0.1	0.4	0.7	2.0	
138	Air-Maze, oily screen for Ford A	Yes	0.10	0.4	1.0	2.0	4.7	
128	Bowden, oily pasteboard for Ford A	Yes 45°	0.15	0.6	2.3	3.5	6.0	
129	Bowden, oily pasteboard for Franklin‡	Yes	0.10	0.3	1.2	2.5	4.4	
133	Gordon, dry felt	No	0.10	0.3	0.6	1.2	2.9	
111	Handy, dry centrifugal ejector	Yes	0.15	0.6	1.8	3.7	6.8	
125	National, oily hair, loose, for Ford A	Yes	0.15	0.5	2.0	3.4	6.0	
136	National, oily hair, loose, for Buick 28-20	No	0.10	0.2	1.1	2.0	4.9	
92	Vortox, self-washing oily wire, Model 850§	Yes	0.50	1.7	3.2	6.7	12.8	Some oil went over at 60 m.p.h.
96	Vortox, self-washing oily wire, Model 1000§	Yes	0.25	0.9	2.3	4.9	8.2	
119	Protectomotor, dry felt, Model C-4§	No	0.10	0.2	0.6	1.5	2.1	
119-*A*	Protectomotor, dry felt, Model C-4§	No	0.10	0.3	0.7	1.7	2.2	After 3 years' use on Extension Division truck
122	Tillotson, dry centrifugal collector, Model X-1	No	0.10	0.4	0.9	2.5	4.0	Practically same as Model OW560
109	United, dry centrifugal ejector with rotor	No	0.33	1.0	2.4	5.6	11.3	
110-A	United, dry centrifugal ejector without rotor	No	0.15	0.5	1.6	3.5	6.5	Inlet facing down air stream
110	United, dry centrifugal ejector without rotor	No	0.10	0.4	1.4	2.6	4.4	Inlet facing air stream
118	United, dry centrifugal ejector without rotor, for Ford A	No	0.15	0.4	1.2	2.4	7.4	
108	Winslow, Down-Flo, self-washing oily screen§	No	0.10	0.3	1.3	2.5	3.5	Trace of oil went over at 60 m.p.h.
Tube *A*	Flexible metal hose, 2¼ in. i. d. x 36 in.	....	0.15	0.4	1.0	2.2	3.3	Used as connection to carbureter.§
Tube *B*	Steel, 1⅝ in. i. d. x 24 in. Has brazed elbows	Two 45°	0.10	0.3	0.8	1.7	3.0	Used as connection to carbureter.‡

* Tests made on a nearly level paved road, in nearly calm air. Average of readings taken for travel in opposite directions. All cleaners clean and freshly serviced unless otherwise specified. Carbureter adjustment left unchanged throughout.

† See description table 1. ‡ Tube *B* was used in one installation of cleaner No. 129 in this road test.

§ Tube *A* was used for cleaners 92, 96, 108, 119, and 119*A* in this road test.

As before indicated, the presence or absence of an elbow in the cleaner outlet may be the main cause of differences in restriction. This is true of cleaners 77 and 138 in table 4, the latter having an elbow and the former none. Similarly, cleaner 136, a National, though slightly smaller than No. 125 of the same make, shows less restriction because it is not handicapped by an elbow. Elbows should be avoided whenever possible. When they are necessary, they should be of ample size and smooth inside.

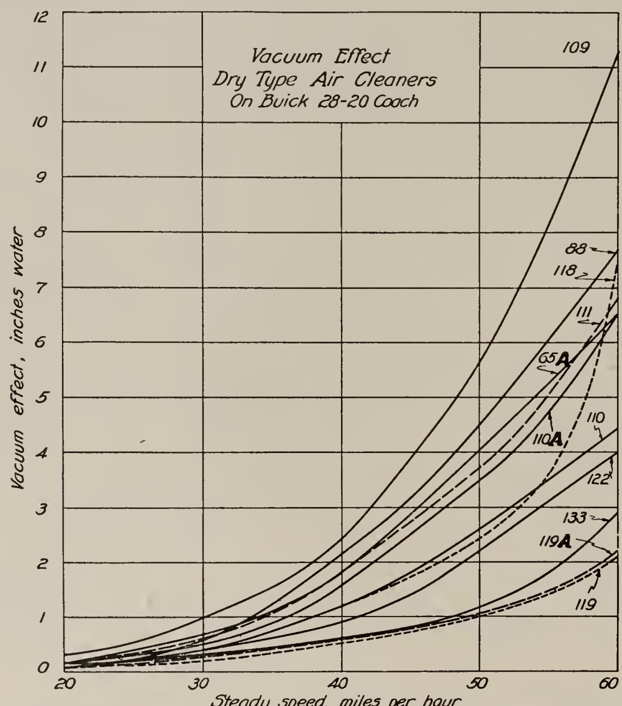

Fig. 36.—Road tests of the restriction or vacuum effect of dry-type cleaners clean or freshly serviced (except 119*A*) applied in succession to carbureter. Car run in calm air on level road, and restriction or vacuum effect measured at speeds 20 to 60 m.p.h.; 119, Protectomotor; 119*A*, same but used 3 years on truck; 133, Gordon; 122, Tillotson; 110, United with inlet facing fan; 110*A*, same, inlet facing from fan; 111, Handy; 65*A*, AC collector; 118, United for Model A Ford; 88, AC ejector; 109, United with rotor.

Cleaner 110, a United dry centrifugal without rotor, was tested in two positions, one with the air inlet facing the blast from the radiator fan (110) and the other (110*A*) facing in the opposite direction. Both these placings are found in practice. As will be noted (table 4), the down-stream facing of the air inlet raised the restriction by about 50 per cent. Nevertheless, this placing is preferable because less dust is taken in than when the inlet faces the fan blast.

Five cleaners designed for the Model A Ford were given road tests of restriction on a coach of that make and model in a manner similar to the tests made on the Buick as described in the preceding paragraphs. The car had been used 7,100 miles and was apparently in good running condition. It should, however, be pointed out that these tests and those on the Buick were not in any sense intended to be tests of the cars but only of the air cleaners.

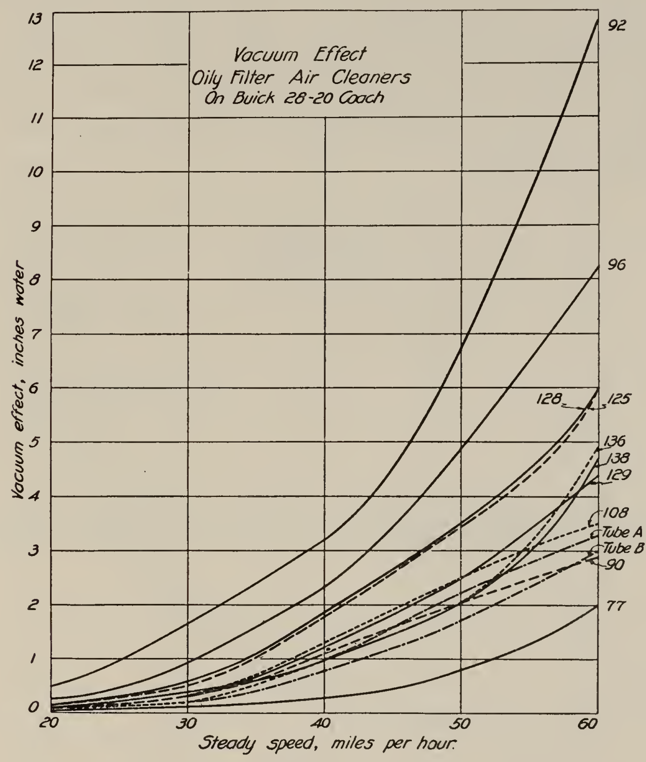

Fig. 37.—Road tests of the restriction or vacuum effect of oily filter type cleaners freshly serviced. Test conditions as for figure 36. No. 77, Air-Maze; 90, AC copper ribbon; 108, Winslow Down-Flo; 129, Bowden; 138, Air-Maze for Model A Ford; 136, National; 125, National for Model A Ford; 128, Bowden for Model A Ford; 96, Vortox, Model 1000; 92, Vortox, Model 850. Tubes: *A*, metal hose 2¼ in. by 36 in.; *B*, seamless steel 1⅝ in. by 24 in. with two 45° elbows.

No adapter tube was used in the tests using the Model A Ford, the cleaner in each case being attached (as intended by the manufacturer) directly to the carbureter inlet. The piezometer ring by which connection was made to the manometer used for measuring the restriction effect of the cleaner was placed on the carbureter inlet tube between the choker butterfly valve and the air inlet. The tests on all

five cleaners were run on the same day. The wind velocity was less than 2 miles per hour. The carbureter was left with the same adjustment throughout all the tests. As will be noted by reference to figure 38 and table 5, none of these cleaners had much effect on the maximum speed that could be maintained on a level road. With no cleaner in use the speed was 60.5 miles per hour; with cleaners 125 and 138 it was 60 m.p.h; with No. 118, 59 m.p.h; with Nos. 143 and 146, 58 m.p.h. Cleaner 118 is designed to be placed with its air inlet facing the fan-blast as in *E* of figure 34. This placing produces a slight supercharging effect which to some extent reduces the restriction at high speeds (as previously noted in the case of cleaners 110 and 110*A*, p. 58) ; but it is not a desirable placing, because more dust must be handled by the cleaner.

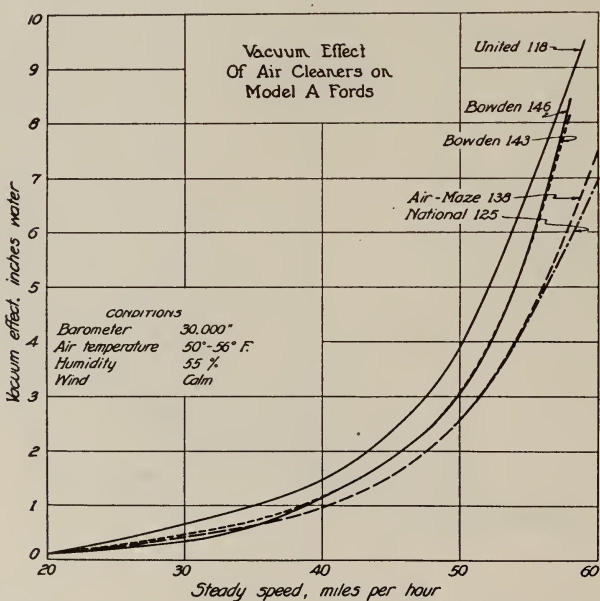

Fig. 38.—Road tests of the restriction or vacuum effect of cleaners designed for Model A Ford. All tests run same half-day on same Ford coach. Carbureter adjustment not touched. Other test conditions as given for figure 36.

It should be borne in mind in a study of tables 4 and 5 and figures 36, 37, and 38, that all the cleaners (except 119*A*) were clean of dust when given the road test of vacuum effect. Some of them increase in restriction very rapidly when dust is taken in, while others are affected but slightly or not at all (see table 3). The former would run up in restriction much faster at the higher speeds in a road test if dust were present in them in appreciable quantity. The ideal

cleaner would be one that would remove all the dust, both coarse and fine, and never offer appreciable hindrance to the free entry of air to the carbureter. As will be noted, a few cleaners approximate this ideal fairly closely.

TABLE 5

ROAD TESTS* OF AIR CLEANER RESTRICTION AND EFFECT ON CAR SPEED ON A MODEL A FORD COACH

No.	Cleaner	Miles per hour 20	30	40	50	58	59	60	Highest speed obtainable, miles per hour
		Restriction, inches of water							
138	Air-Maze, oily screen	0.10	0.45	0.98	2.60	....	....	7.50	60
143	Bowden, oily pasteboard	0.10	0.48	1.14	3.10	8.13	....	....	58
146	Bowden, oily pasteboard	0.10	0.35	1.16	3.02	8.40	....	....	58
125	National, loose oily hair	0.10	0.38	0.98	2.63	....	....	7.00	60
118	United, dry centrifugal ejector, 4 slots	0.10	0.67	1.48	3.90	....	9.50	....	59
	Without any air cleaner	....	....	....	....	....	....	....	60.5

*The car had run 7,100 miles. The road was paved and nearly level. The air was calm during the tests, had a temperature of 50° to 55°F, a pressure of 30.000 inches mercury, and relative humidity 55 per cent. The carbureter adjustment was untouched throughout the tests. The cleaners were all clean and late models designed for Model A Fords. (See table 1 and figs. 7, 8, and 24).

Effect of Restriction on Power.—How restriction affects power is shown for a Weidely model M A U, 4-cylinder, 25-hp. engine in figure 39. The engine was put into good condition and adjustment, and the maximum power obtainable at 1216 r.p.m. was measured by a Sprague electric dynamometer, the air at first going directly into the carbureter. The machine developed 27 hp. The vacuum at the inlet was then increased step by step by gradually closing an attached gate-valve. After careful adjustment and readjustment of the needle valve for highest power at each step of restriction, the power output was measured. As shown by the left-hand end of the curve, the drop in power was negligibly small for the first 3 or 4 inches of restriction; but thereafter it became larger, until at 20 inches the power had dropped to 95.5 per cent of the original and at 40 inches to 88 per cent. Restriction effects as high as these are found at times in closely woven, felted, or packed dry filter and oily filter cleaners when used on automobiles or trucks and not cleaned out often enough.

The curve of figure 39 shows the power drop *if the needle valve is kept adjusted for maximum power.* On many automotive vehicles it is not feasible for the driver to make such adjustments. Hence in the usual practical case the power would probably fall off much faster than is shown in the figure.

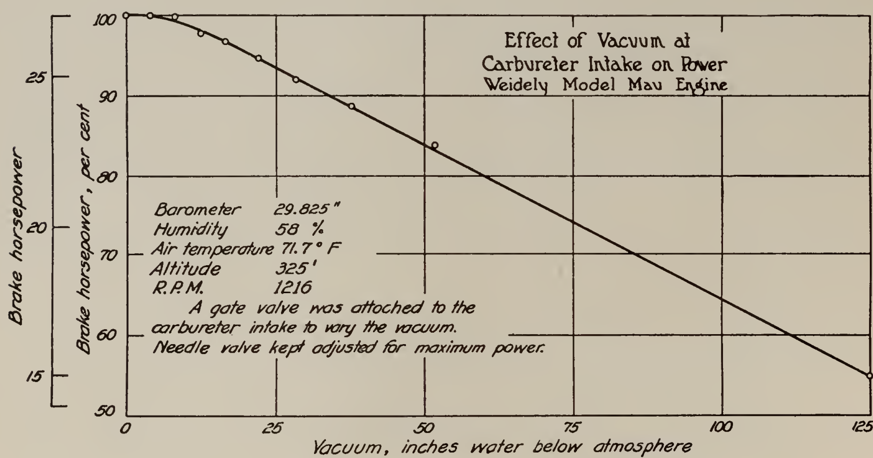

Fig. 39.—Effect of air cleaner restriction or vacuum on power. The curve shows what may be expected when the cleaners are clean and the carbureter needle valve is kept adjusted for maximum power. Ordinarily such adjustment cannot be readily made, and the drop in power would be more abrupt. (Table 3 indicates what restriction may be expected from the cleaners tested.)

BREATHER CLEANERS

Breather air cleaners are designed to prevent the entry of dust into the crankcase with the air that, because of the motion of the pistons, pulsates into and out of the oil filler tube and any other openings into the crankcase. The breather air cleaner is a valuable accessory on tractors, trucks, and automobiles in general, but is needed most on engines equipped with crankcase ventilator. The ventilator usually draws in air through an opening near one end of the crankcase and discharges it from the opposite end. If the inlet opening is not well protected, the benefit to be derived by ventilation may be more than offset by damage done by the extra dust drawn in. As in carbureter air cleaners, high efficiency without restriction is desired. Because the volumes of air to be handled are small, breather cleaners may be small and yet not offer enough restriction to cause dusty air to be sucked in or oil to be forced out through small openings in bearings or gaskets.

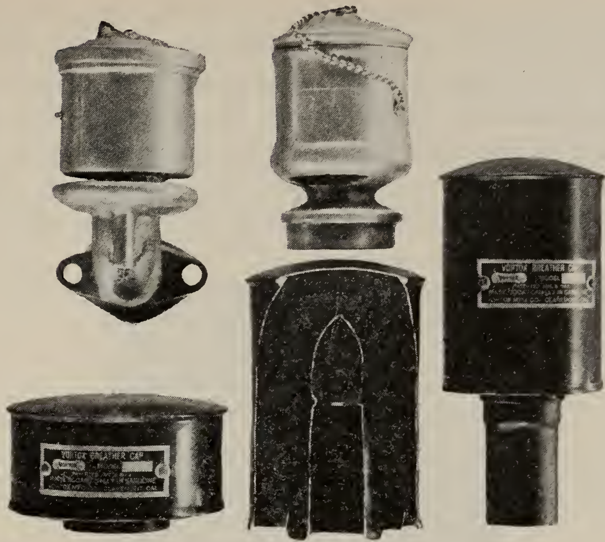

Fig. 40.—Breather air cleaners or 'breather caps.' Both of the two kinds on the market, Vortox (lower three) and Winslow (upper two), are efficient, self-washing oily fiber types that drain to the outside and usually require very little attention. The middle Vortox is partly cut away to show the construction.

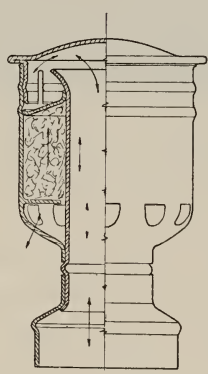

Fig. 41.—Construction of Winslow breather cap. The top lifts off when oil is to be put into the crankcase. Oil may be spilled into the filter material to wash it, though usually condensed vapors from the crankcase are sufficent for this purpose.

Two makes of breather caps, the Vortox and the Winslow, are on the market (fig. 40). Both are of the closely packed oily fiber filter type. When used on the oil-filler tube, the Vortox is designed to be lifted off and may be washed and reoiled by dipping. The Winslow (fig. 41) has a lid that is lifted, exposing the top of the filter and of a central tube for filling the crankcase. The filter may be washed in

place by pouring kerosene through it and reoiled by spilling some over it when oil is added to that in the crankcase. Both the Vortox and the Winslow breather caps are so designed that the dirt is caught in the lowest outer portion of the filter and automatically washed out by condensed oil and water vapors from the crankcase, when used on crankcases not provided with a ventilator. Thus they serve effectively and without any attention throughout the life of the machine.

Fig. 42.—An inward-draining breather cleaner. This cleaner, probably on account of insufficient servicing, became clogged and caused bearings to 'burn out' because the oil was forced out through the bearing clearances and gasket leaks.

Where, however, there is a crankcase ventilator, the oily vapors are lacking in the cleaner covering the inlet opening; hence cleaning and reoiling are necessary after each 5,000 to 10,000 miles' use. Draining to the outside is decidedly advantageous because it removes much of the acid that might otherwise remain in the crankcase.

Several tractor and automobile manufacturers use breather air cleaners of their own design. Some of these are quite similar to those shown in figure 40 and are of satisfactory efficiency; but in others the filter elements are too thin and loose. In many machines the breather air cleaners are not readily accessible or are hidden behind other parts and therefore liable to be neglected when the machine is serviced. Some of these built-in breather cleaners are so designed that the dirt and condensed vapors of oil and water will drain back into the crankcase, the filter itself being depended upon to hold the accumulated

dirt until the cleaner is serviced. This is not a desirable construction. Figure 42 shows such a breather cleaner. This cleaner rather suddenly developed very high restriction and is reported to have caused all the oil to be forced out of the crankcase. The failure may have resulted either from insufficient servicing or from distintegration of the organic fibers of the filter.

An interesting attempt to combine air cleaner, oil-filler tube, crankcase ventilator, and self-washing breather cleaner is shown in the Winslow Purifier, cleaner No. 84, figure 16.

SUMMARY

1. A good air cleaner properly installed and serviced means less engine wear, less trouble, less expense (for fuel, oil, repairs, breakdowns), quieter running, and greater dependability.

2. An air cleaner has no adequate reason for existence unless it can remove dust from air.

3. A cleaner should offer the least possible restriction to the passage of air through it.

4. Most of the air cleaners now sold, if properly selected as to size for the engines on which they are used and if kept clean, do not appreciably affect the power or acceleration of road vehicles at speeds of 40 m.p.h. and under. Above 40 m.p.h. the effects of high restriction and of insufficient servicing are much more marked.

5. Air inlets should not face the blast from the radiator fan.

6. Elbows and long tubular connections should be avoided.

7. Air-leaks in the connections between the air cleaner and the carbureter are detrimental. They should be closed securely.

8. All good air cleaners require some servicing. Neglect usually means decreased efficiency and increased restriction.

9. Air cleaners of different makes and types differ markedly in their behavior in use.

10. The dry-centrifugal type cleaners now marketed do not afford adequate protection. At low air speeds this type loses practically all of its efficiency.

11. Dry filters tightly woven or felted and tightly packed plain oily filters afford good protection but have often caused trouble from increasing restriction when not sufficiently serviced.

12. Plain oily filters loosely packed usually do not offer much restriction, even if neglected, unless clogged by leaves, chaff, or insects.

Many are too thin to afford satisfactory protection; some give excellent protection if sufficiently serviced.

13. Self-washing oily filters, if well designed and sufficiently serviced, generally afford excellent protection even in extreme dust. This type is well adapted for tractors, large trucks, and busses. Some makes have low restriction; others somewhat higher. Some are simple in design, others are rather complicated. In some the washing action is vigorous and effective; in others it is inadequate.

14. An efficiency test of an air cleaner has little significance unless the dust used is very similar to that which the cleaner must handle in regular service.

15. Most air cleaners to some extent muffle carbureter noises. Many of them also serve to minimize the danger of gasoline being ignited by backfires. The principle of the Davy safety lamp applies: chilling the burning gases by passing them through small openings in metal or other heat-absorbing material.

ACKNOWLEDGMENTS

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282. Prevention of Insect Attack on Stored Grain.
284. The Almond in California.
287. Potato Production in California.
288. Phylloxera Resistant Vineyards.
289. Oak Fungus in Orchard Trees.
290. The Tangier Pea.
292. Alkali Soils.
294. Propagation of Deciduous Fruits.
295. Growing Head Lettuce in California.
296. Control of the California Ground Squirrel.
298. Possibilities and Limitations of Cooperative Marketing.
300. Coccidiosis of Chickens.
301. Buckeye Poisoning of the Honey Bee.
302. The Sugar Beet in California.
304. Drainage on the Farm.
305. Liming the Soil.
307. American Foulbrood and Its Control.
308. Cantaloupe Production in California.
309. Fruit Tree and Orchard Judging.
310. The Operation of the Bacteriological Laboratory for Dairy Plants.
311. The Improvement of Quality in Figs.
312. Principles Governing the Choice, Operation and Care of Small Irrigation Pumping Plants.
313. Fruit Juices and Fruit Juice Beverages.
314. Termites and Termite Damage.
315. The Mediterranean and Other Fruit Flies.

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